ASTRONOMY

June 1981
$2
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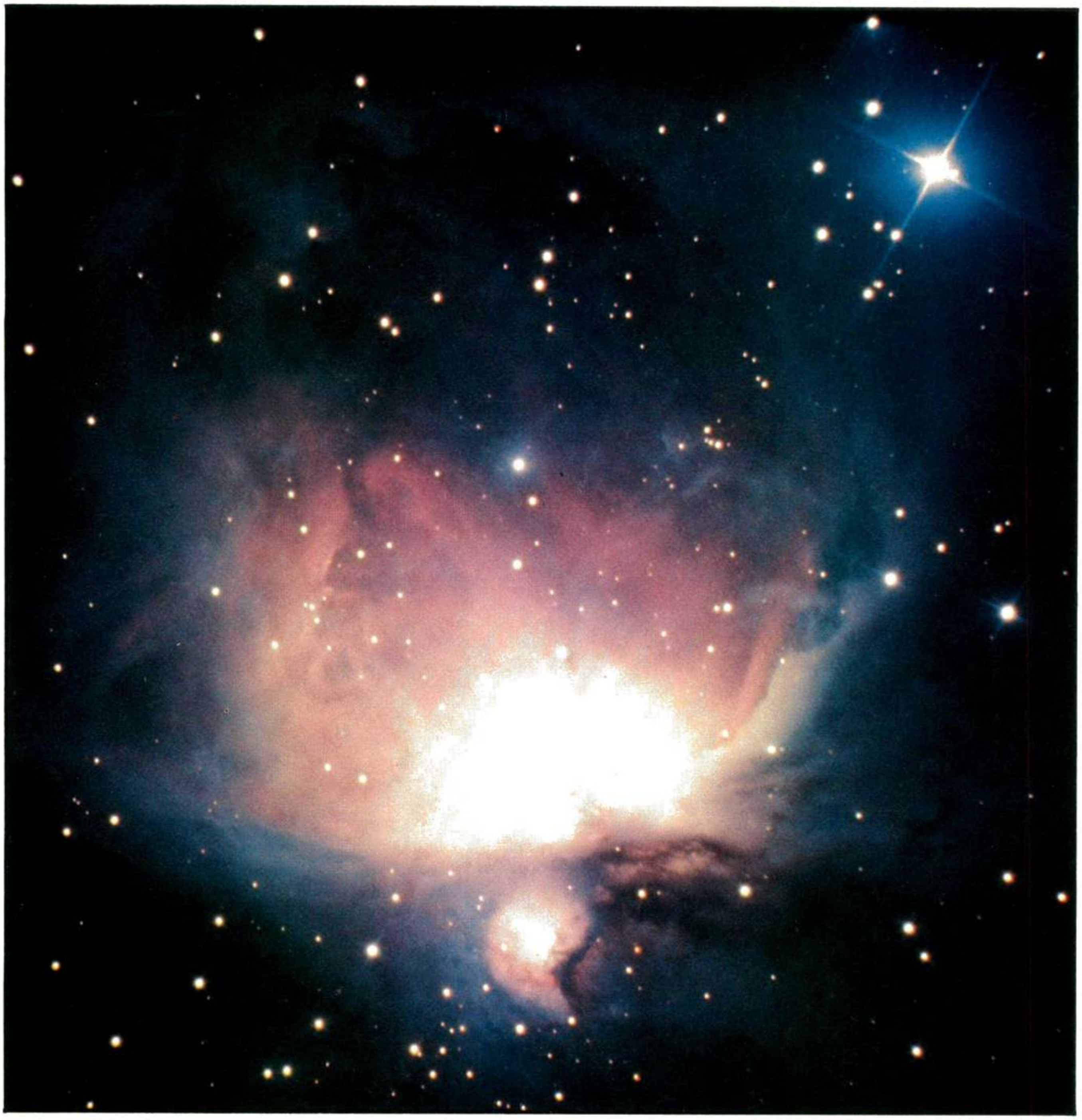
Probing the Chemistry of Galaxies

Flare Stars: Those Feisty Little Suns

Getting the Correct Exposure



Cosmic Cauldron — the Orion Nebula

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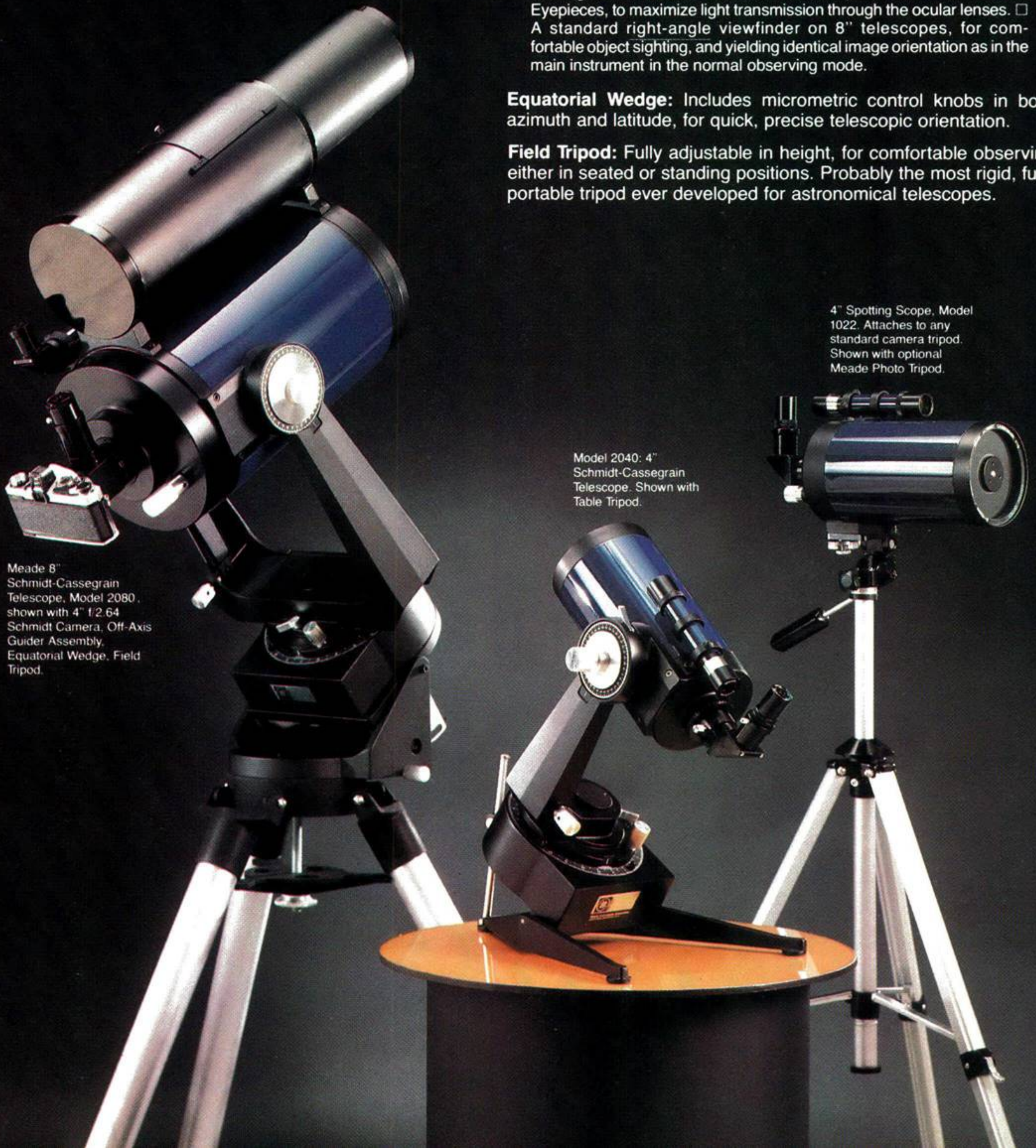

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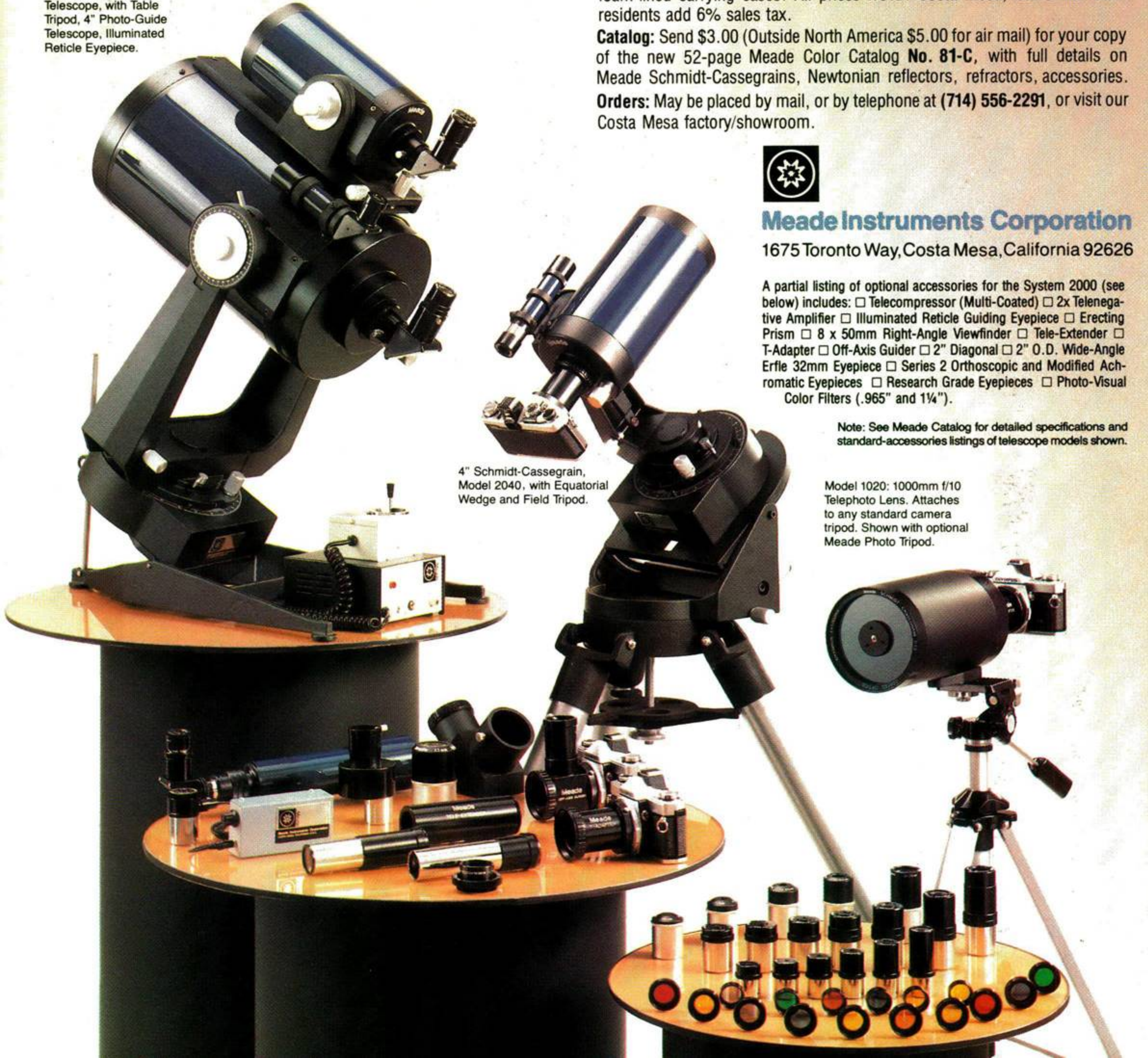

Model 2080: 8" Schmidt-Cassegrain Telescope, with Table Tripod, 4" Photo-Guide Telescope, Illuminated Reticle Eyepiece.

4" Schmidt-Cassegrain, Model 2040, with Equatorial Wedge and Field Tripod.

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Note: See Meade Catalog for detailed specifications and standard-accessories listings of telescope models shown.

ASTRONOMY

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Cover: The Orion Nebula is a region where new stars are born from mixtures of dust, hot hydrogen, and other chemical elements; the arms of spiral galaxies abound in such regions. In contrast, the nuclei of spiral galaxies like M-31 (these pages) contain mostly old stars deficient in chemical elements. This month ASTRONOMY features a look at the chemistry of these and other galaxies. Cover photo by Roger Sliva; these pages, Kitt Peak National Observatory.

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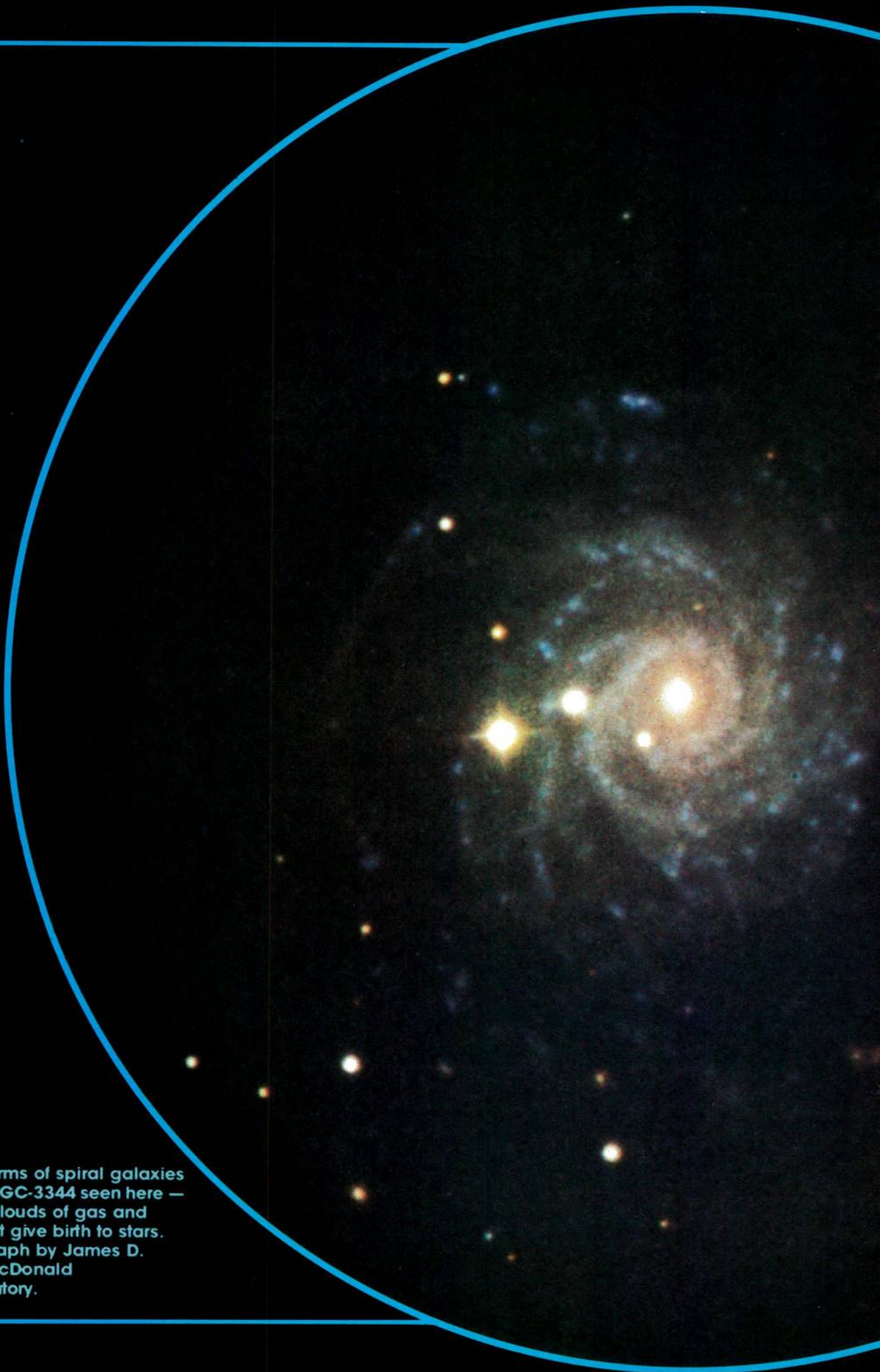
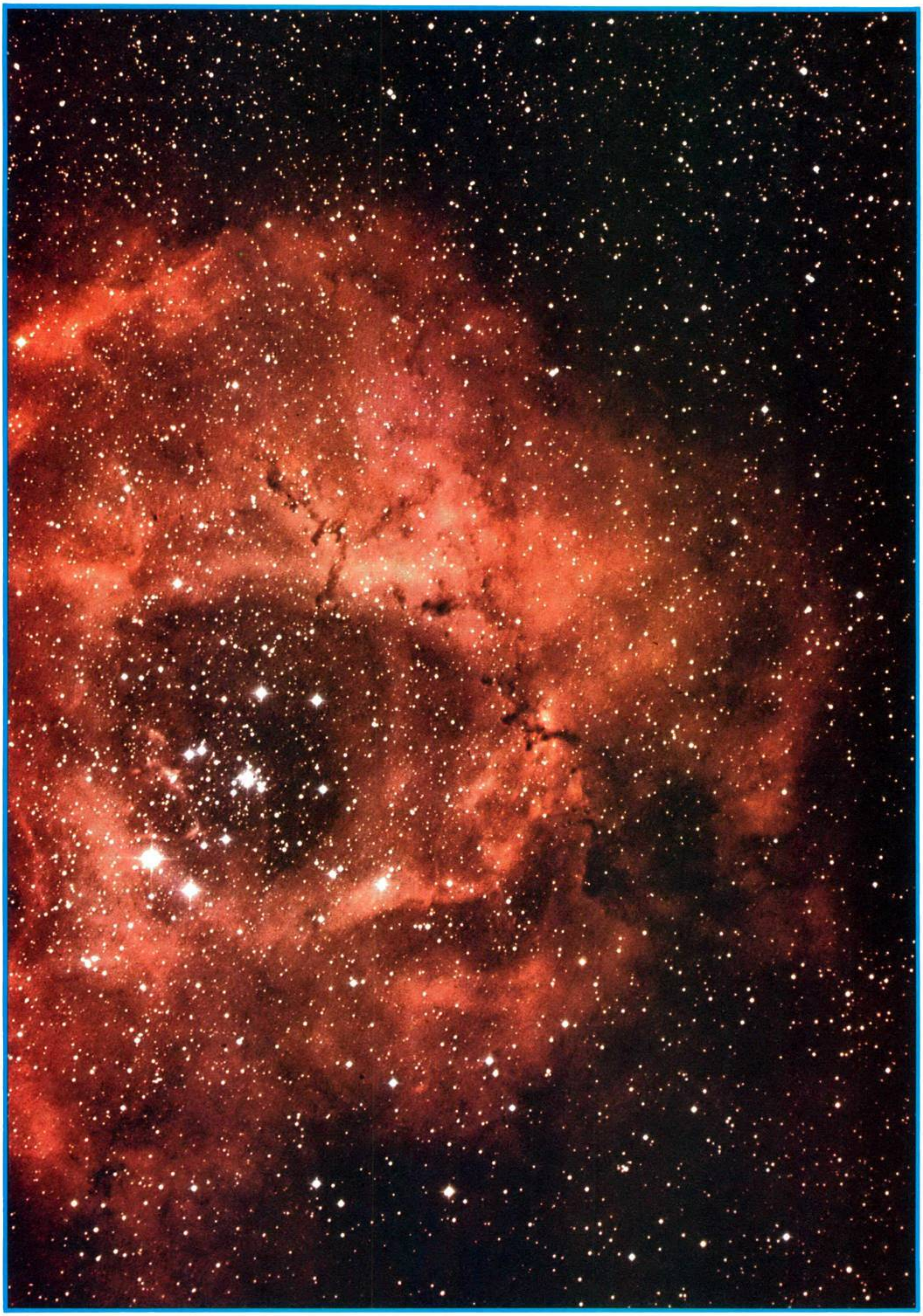


In the arms of spiral galaxies — like NGC-3344 seen here — lie the clouds of gas and dust that give birth to stars. Photograph by James D. Wray, McDonald Observatory.

The Chemistry of Galaxies

by Gregory Shields

A hundred billion suns circling in a community thousands of light-years across — majestic gas clouds from which countless stars will form — stars dying in stupendous explosions, scattering debris over vast distances: This is our Milky Way, one of the many building blocks of the universe we call galaxies.



In practical terms, low-mass stars remove material from the interstellar material forever.

For a massive star, the end comes in a titanic supernova explosion which blasts elements "cooked" in its nuclear furnace back into the interstellar medium. The gas, rich in new elements, will slowly spread through the medium and join material thrown off by other stars. Crab Nebula photograph from Lick Observatory.

The discovery of galaxies, and the study of their forms and locations, has been one of the triumphs of 20th century astronomy. Our challenge today is to understand how galaxies came to be what they are. This task will draw on astronomers' knowledge of subjects ranging from nuclear physics to the origin of the universe. As a part of this effort, astronomers have recently intensified their investigation into what chemical elements compose the stuff of galaxies. But in order to understand the chemistry of galaxies, we need to know something about their structure and origin.

Galaxies exist in three main types: spirals, ellipticals, and irregulars — and each type varies considerably in size. The Milky Way is a spiral galaxy of average size. Most of its stars and nearly all its interstellar gas lie in a flattened, circular disk held together by gravity. Our Sun follows a circular orbit within the disk, about 30,000 light-years from the center — approximately half way to the rim.

Near the center of the galaxy, the disk swells up into a thicker, more nearly spherical concentration of old stars called the "bulge." A much larger almost spherical volume of very old stars called the "halo" lies at a greater distance from the center. New stars are constantly forming from the gas in the disk, their birth triggered by the passage of spiral-shaped compression waves. The resulting bright young stars outline the waves and create the conspicuous spiral pattern for which these galaxies are known.

Roughly half the large galaxies in the sky are spirals, ranging in size from about ten times the mass of the Milky Way to one-tenth of it. The total mass of gas in the Milky Way is a few percent of its mass in stars. Some spiral galaxies have a larger gas fraction, and others, a smaller one.

But most galaxies in the sky are ellipticals: these have a smooth oval outline in photographs, although astronomers are still unsure whether their 3-dimensional forms are prolate (egg-shaped), oblate (doorknob-shaped), or something more complicated. Elliptical galaxies consist of old stars and little gas, rather like the bulges of spiral galaxies. But ellipticals have no disk — loosely speaking, they're all bulge. Ellipticals range from giants hundreds of times more massive than the Milky Way to dwarfs with only a few million stars.

The third type of galaxy is the irregular. These galaxies have even more gas, in proportion to stars, than do spirals. In some irregulars, gas makes up nearly half the total mass. Part of the gas is concentrated in large clouds where it produces lots of new stars, thus giving irregulars their characteristic patchy appearance. Most irregular galaxies are smaller than the Milky Way; the closest are the two Magellanic Clouds, which orbit the Milky Way at a distance of several hundred thousand light-years.

Scattered throughout the Milky Way lie many clouds of gas and dust in which we see hot, young stars. Those of the Rosette Nebula vary greatly in size. Some are small and will outlast the Sun, but others are massive and squander their resources recklessly — blazing for only a few million years before flickering out. Hale Observatories photograph.

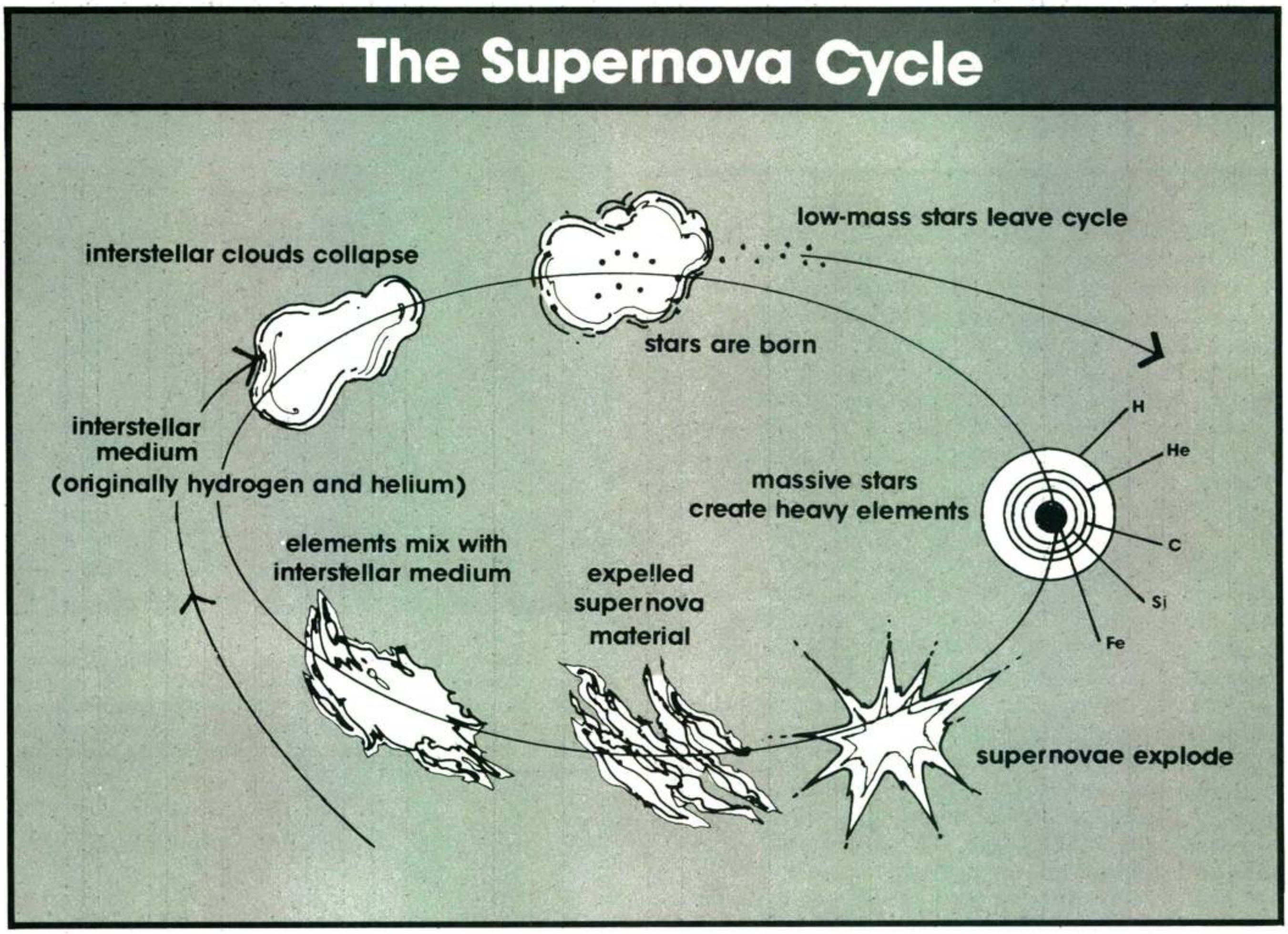
During the 1920s and 1930s, astronomers noticed a continuity between the different types of galaxies. The spirals with relatively little gas in their disks have prominent bulges. Remove their disk and they would resemble the more flattened of the elliptical galaxies. On the other hand, the most gas-rich spirals have inconspicuous bulges, and most are rather small. If you were to mess up their spiral pattern, you'd have something that looked like an irregular galaxy.

Edwin Hubble used this progression in type from elliptical to spiral to irregular as the basis for a simple classification scheme: elliptical galaxies carry the symbol "E"; spirals, "S"; and irregulars, "Irr." Spirals are further subdivided into types Sa, Sb, Sc, and Sd in order of increasing gas content and decreasing bulge size.

Interstellar Laboratories

In most galaxies with large amounts of gas, new stars are constantly being born as portions of the gas contract under the force of gravity. In our Galaxy, star formation is especially prevalent in massive, "dark" clouds of gas and dust that have condensed out of the more tenuous gas permeating the galactic disk.

Typically, when a large number of stars are born from a gas cloud, they have a variety of masses — ranging from over 10 times the mass of the Sun to perhaps only one-tenth of it. The massive stars are extremely bright and hot, and emit great amounts of ultraviolet light. Absorbed by the surrounding gas, the light removes some of the electrons from the atoms in the gas, a process called ionization. The



The Supernova Cycle

interstellar clouds collapse
low-mass stars leave cycle
stars are born
interstellar medium (originally hydrogen and helium)
massive stars create heavy elements
H
He
C
Si
Fe
elements mix with interstellar medium
expelled supernova material
supernovae explode

resulting volumes of hot, ionized gas are known as "H II" regions because astronomers so designate ionized hydrogen, the clouds' most abundant element.

A familiar H II region is the Orion Nebula (M-42), which is energized by the hot young stars of the Trapezium. Because H II regions emit visible light as well as radio, infrared, and ultraviolet radiation, they are sometimes called emission nebulae.

But H II regions are good for more than pretty pictures. Observed with a spectrograph, they show lines emitted by ions of various elements, each at its own unique wavelength. From the relative brightness of different emission lines, astrophysicists can deduce the temperature and density of the gas, and the proportions of some of its chemical elements.

The Orion Nebula has a temperature of about 10,000° K and a density of a few thousand atoms per cubic centimeter — almost a billion billion times more rarefied than the air around us — but its diameter of roughly 10 light-years gives it a mass of about 10,000 suns. The chemical composition of the Orion Nebula is fairly close to that of the Sun: for every million atoms of hydrogen, there are about 100,000 atoms of helium, several hundred each of carbon, nitrogen, oxygen, and neon, and a few dozen of iron and other elements.

Cosmic Alchemy

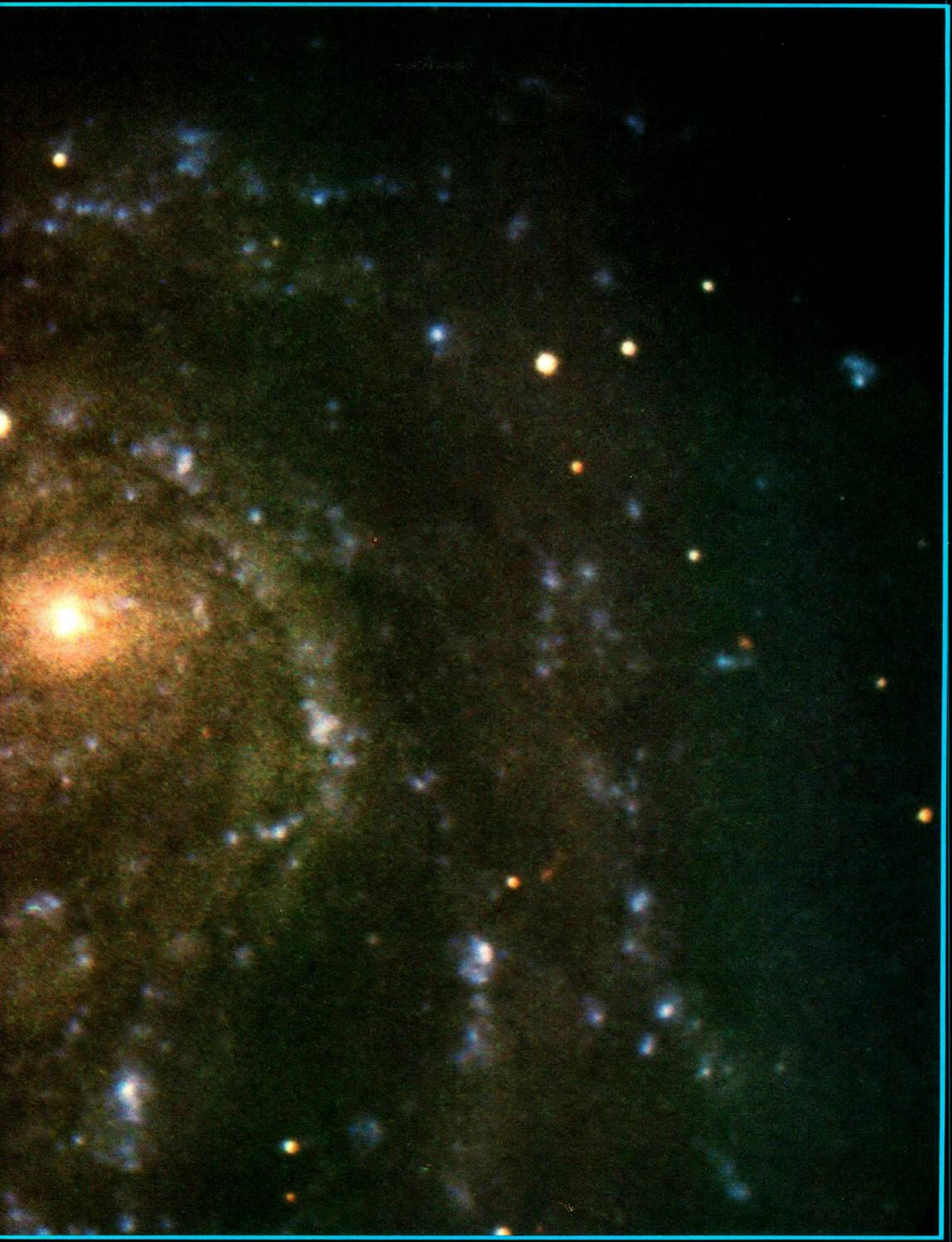
Astronomers have made some progress in understanding how this mixture of elements came to be. For part of the answer, we must go back to the earliest moments of the universe. Most astronomers accept the Big Bang model in which the universe was born in an instant of infinitely high temperature and density. Ever since, the universe has been expanding — its material steadily thinning out and its temperature steadily dropping.

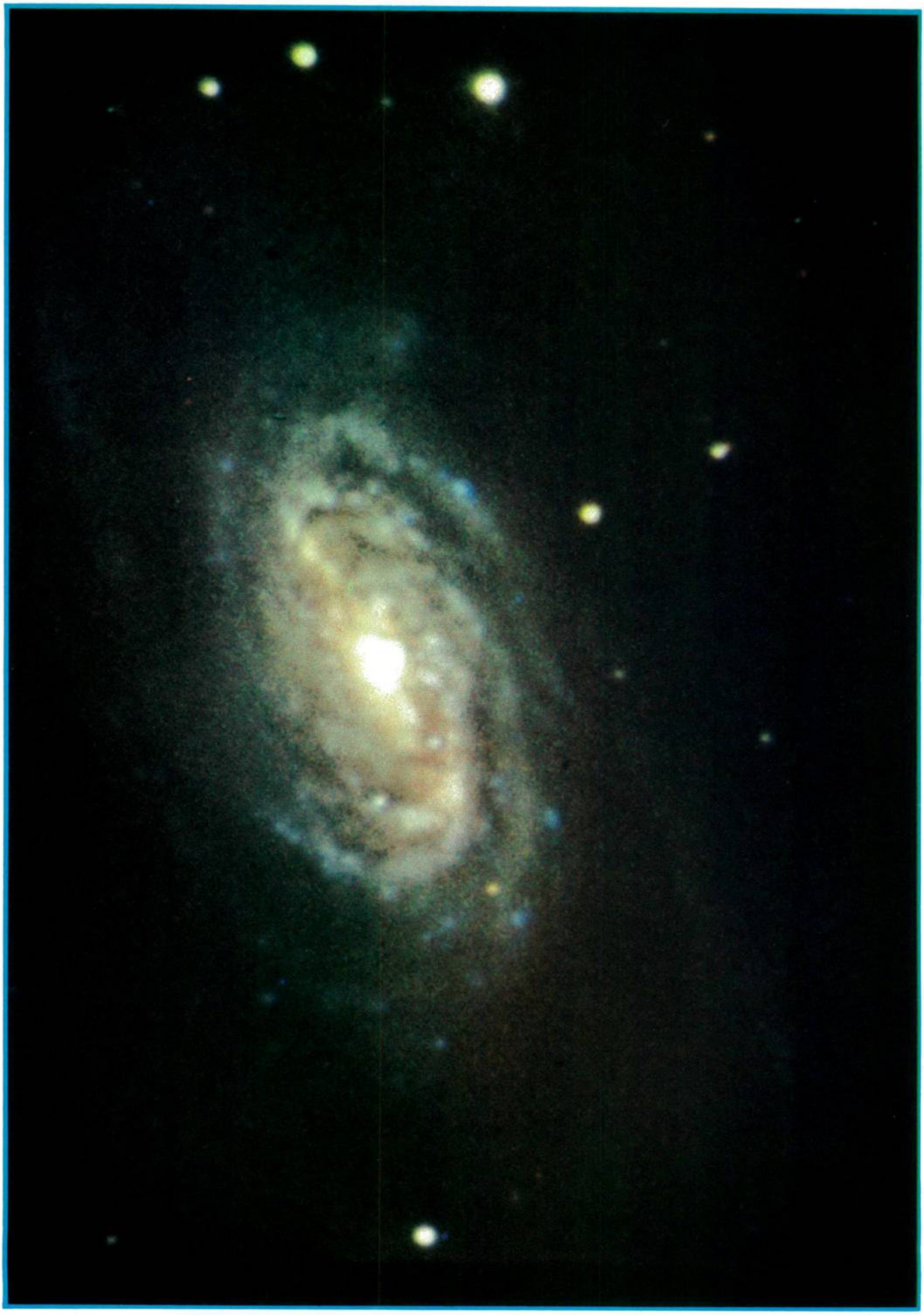
When the universe was less than one minute old, it was so hot only elementary particles (protons, neutrons, electrons) could exist — no atoms or even atomic nuclei could survive. This material spread uniformly throughout space. About three minutes after the beginning, the temperature had fallen to a few million degrees, and some simple nuclei, mainly deuterium and helium, were formed by the collisions of neutrons and protons. After a few more minutes, the temperature and density were too low for this nuclear fusion to continue.

Detailed calculations show that this period of *primordial nucleosynthesis* should have produced about seven helium nuclei for every 100 hydrogen nuclei. This much primordial helium should still be present everywhere in the universe, since nothing has happened to destroy significant amounts of it.

Galaxies were born much later. When the universe was getting on toward a million years old, regions of slightly increased density in the expanding

Right: In M-61, as in many spiral galaxies, the central bulge contains old reddish stars and little gas. Around it lies the flattened disk, knotty with areas of fresh star-formation. Overleaf: M-101, a type Scd spiral galaxy, displays the small nucleus and large disk common to its type. Photographs by James D. Wray, McDonald Observatory.





gas began to grow more pronounced. After roughly 100 million years, these regions broke away from the overall expansion of the universe and began to contract under their own gravity as separate clouds.

When the gas in such a cloud compressed sufficiently, stars began to form — and a galaxy was born. We don't yet understand exactly what causes some galaxies to become ellipticals and others spirals or irregulars, but the mass of the galaxy and its speed of rotation play important roles.

The Big Bang did not produce large amounts of elements heavier than helium. To explain the observed amounts of such elements as oxygen and iron, astrophysicists turn to another kind of nuclear furnace: the star.

The Sun shines with energy produced when hydrogen fuses into helium in its interior — a process used by every star for most of its life span. When its hydrogen is used up, a star rearranges itself in order to raise its internal temperature high enough to begin "burning" — fusing helium into yet heavier nuclei, including carbon and oxygen. If the star is massive enough, the process may continue until iron is produced. But iron is the end of the line: building heavier nuclei takes more energy than it releases.

Spreading the Wealth

If these heavy elements remained locked away in the centers of stars, they'd have little effect on the mixture of elements in galactic gas. But every star having more than a few times the mass of the Sun will make quite a commotion when it dies. Originating in the core and tearing upward through the layers of gas, an explosion blasts much of the star's material out into space at speeds of thousands of kilometers per second. The expanding cloud of hot gas radiates a tremendous amount of light — enough, during the first few weeks after the "bang," to rival that of an entire galaxy. Such an outburst is a supernova.

Centuries pass, and the expanding gases become visible as a ragged, glowing nebula. The Crab Nebula in Taurus (900 years old) and the still-older Veil Nebula in Cygnus are typical examples.

The supernova debris contains material — rich in fusion-generated heavy elements — from deep within the star. Helium makes up most of the Crab Nebula, and the supernova remnant Cassiopeia A contains some fragments that are mostly oxygen and others that are mostly sulfur and argon.

Astronomers believe that all the elements heavier than helium were forged in ancient stars that long ago exploded and scattered them into interstellar space. Later, new stars — and probably solar systems — were formed out of the contaminated gas. The Sun is a second or third generation star and, of course, the Earth and its inhabitants are made of such materials.

When each new generation of stars forms, a number of them have small masses. These low-mass stars burn their nuclear fuel very slowly, living for many billions of years and never becoming supernovae. In practical terms, they remove material from the interstellar gas forever. But not all new-generation stars have low masses: some are massive and live only a few million years — just an instant on the galactic timescale. Then they explode and return much of their original gas, enriched again by heavy elements produced in their cores, to the interstellar medium.

The passage of spiral-shaped waves through the disk of a galaxy triggers star-formation by compressing gas clouds to the point where they contract under their own gravity. The hot stars that result outline the waves and create spiral patterns such as those seen here in NGC-2903. Photograph by James D. Wray, McDonald Observatory.

Dust grains and gas — the elements of star-formation — may come from many sources. Supernovae, flare stars, and dispersed planetary nebulae all add their by-products to the hydrogen and helium left from the Big Bang. As time passes, the interstellar gas becomes more and more enriched. Lagoon Nebula photo from Kitt Peak National Observatory.

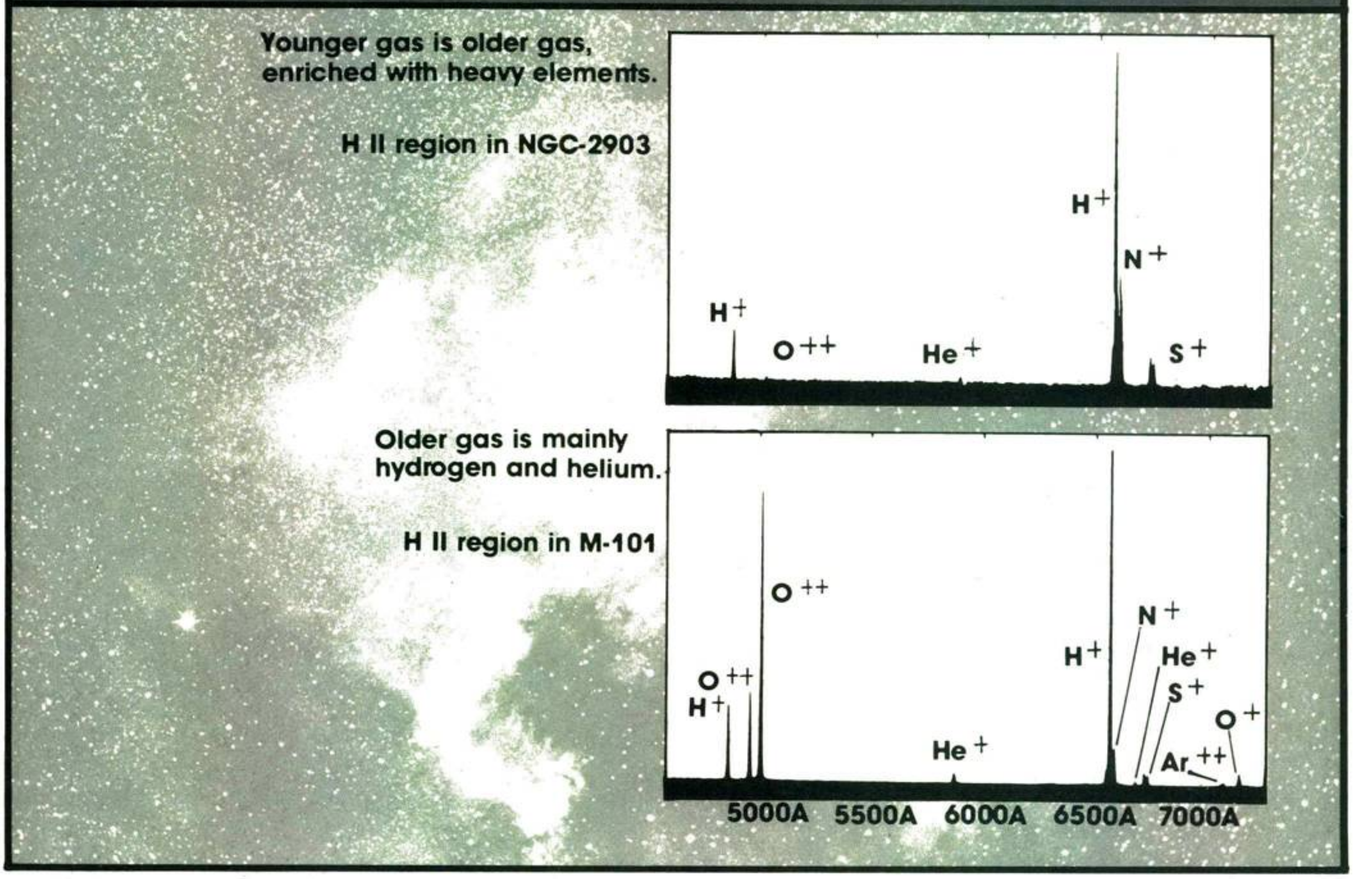
The "ecology" of the interstellar gas involves consumption by each generation of stars, partial recycling, and enrichment with heavy elements. As the process goes on, more and more material gets locked up permanently in low-mass stars, and heavy elements become increasingly more abundant in the dwindling supply of interstellar gas.

This picture, called the "simple model," leads to an important prediction. When our Galaxy was young, the interstellar gas should have been less rich in heavy elements than it is today. Stars that are now old were formed from this early mixture and should be low in heavy elements — to match the low abundances the interstellar gas had at their birth. On the other hand, young stars should show higher abundances and heavier contamination because they are formed from partially enriched gas.

We can test this prediction observationally, since spectroscopic studies of stars tell us about the abundance of heavy elements in them. In a general way, the measurements agree with the theory. The stars in the galactic halo are very old, and indeed have heavy element abundances only a tenth or a hundredth of the Sun. Similarly, older stars in the disk of the Milky Way have lower abundances than young stars.

However, the simple model predicts there

Spectroscopic Probes of Composition



should be a lot more stars with low abundances than we actually find. Since this discrepancy is based mainly on observations of G-type (medium temperature) stars like the Sun, astrophysicists have called it the "G-dwarf problem." It implies that the simple model does not approximate very closely what really happened during our Galaxy's history.

Unfortunately, there's no agreement on a better model. One possibility is that, as star formation proceeded, fresh, uncontaminated gas kept falling into the disk from intergalactic space outside the Milky Way. Calculations show this would lead to stars with abundances similar to what we see.

Beyond the Milky Way

In their search for more clues about chemical evolution, astronomers have been looking outside the Milky Way to the galaxies beyond — a search that has intensified in the last decade as sensitive electronic spectrographs have made it possible to observe H II regions in more distant galaxies.

Not surprisingly, the studies have included the Magellanic Clouds. The heavy elements in the interstellar gas of these galaxies are several times less abundant than in the Sun. This fits with the fact that irregular galaxies have great quantities of gas, which in turn suggests that the evolutionary process of star formation and heavy element production is less advanced there than in the Milky Way.

Studies of a number of irregular galaxies, notably by Bernard Pagel and his coworkers in England, have shown that the irregulars with the largest proportion of gas have the lowest abundances. This hints that the simple model may describe fairly well the history of irregular galaxies.

These irregulars may have something profound to say about the nature of our universe. Because the gas in them has suffered relatively little contamination by stellar evolution, we can estimate how much helium existed there before stars added their contribution. Theoretical calculations say that the amount of primordial helium depends somewhat on the properties of the universe. Current measurements of the primordial helium abundance agree with models in which the universe is infinite in extent and will expand forever. However, these measurements are so difficult to make and interpret that most astronomers don't accept the current results as conclusive.

Although the chemical composition of gas is nearly the same everywhere within an irregular galaxy, it varies within spiral galaxies. Ten years ago, Leonard Searle of Hale Observatories found that H II regions near the center of spiral galaxies have different spectra than those near the outer edge of the disk — an indication that chemical composition changes with distance from the center.

Subsequent studies have shown that, in the case of the giant spiral galaxy M-101, the ratio of oxygen to hydrogen drops by a factor of ten from the inner disk to the outer disk. The proportion of nitrogen to oxygen may also decrease. The nature of these "composition gradients" depends on the galaxies'

The simple model may not approximate very closely what really happened during our Galaxy's history.

appearance (Hubble classification type).

Types Sb and Sc have relatively high abundances, while Sd types have abundances almost as low as irregular galaxies. The strongest gradients appear to occur in the "Scd" types (like M-101) that are in between the Sc and Sd types. These have high abundances near the center, but low abundances in their outer disks — similar to those found in irregular galaxies.

To gather more information about the chemistry of galaxies, a group at the University of Texas at Austin consisting of Marshall McCall, Paul Rybski and myself has observed the spectra of H II regions in a variety of spiral and irregular galaxies. These observations were made over the past several years with the large telescopes at McDonald Observatory and Kitt Peak National Observatory.

Our plan was to study galaxies that differed from M-101 in some well-defined way — such as size, morphological type, or environment. The majority of galaxies conform to the trend of decreasing abundance from Sb types to the Sd types. However, we have found several intriguing exceptions.

The Sbc galaxy NGC-3344 should have high abundances all across its disk, but in fact has a composition gradient much like M-101. On the other hand, NGC-6946 is an Scd galaxy that closely resembles M-101, yet has higher and more uniform abundances usually found in the Sb type galaxies. Why do these galaxies deviate from the norm? We don't know for certain.

One possible answer is that NGC-6946 has no close neighbors in space, but M-101 resides in a group of closely-spaced galaxies. Could the different environments of these two galaxies have affected their chemical evolution?

Astrophysicists don't yet understand where composition gradients in spiral galaxies come from. Calculations by Beatrice Tinsley and Richard Larson of Yale University indicate that the radial variations in abundance are larger than the simple model calls for. It seems likely that the solution involves some type of large-scale gas flows from one part of a galaxy to another, or between a galaxy and its surroundings. The "G-dwarf" problem mentioned earlier suggests that gas falling into the disks of spiral galaxies may be important.

Another possibility is that the energy released by supernova explosions may sometimes overpower the gravity of a galaxy and expel the contaminated gas. If the supernova debris can escape more easily from the outer regions of a galaxy, it's easy to understand why these regions have a smaller proportion of heavy elements than the inner regions. The fact that heavy element-poor spiral and irregular galaxies generally have smaller masses than element-rich Sb types also supports this idea. In addition, Sandra Faber of Lick Observatory has presented evidence that the stars in small elliptical galaxies have lower heavy element abundances than do large ellipticals, which are tightly bound by gravity.

Made luminescent by the fierce radiation emitted from the bright, young stars embedded within it, the gas of the Eagle Nebula marks a "stellar nursery" where stars are born. Silhouetted across the face of the ionized hydrogen gas are many cold, dark globules of dust. Photograph from Kitt Peak National Observatory.

Where Do We Go From Here?

Defining the chemistry of galaxies is a complex and challenging problem. Many unknowns contribute to the evolution of galaxies, and a wide variety of measurements will be needed to pin down the truth. We need to extend and improve our observations of the stars and gas in galaxies, and we must determine the nature of the enigmatic "dark mass" that lurks around and between them.

We also need a better understanding of the birth, evolution, and death of stars. Measurements of radioactive elements in meteorites, already incredibly precise, must be continued in search of clues to the kind of supernova explosions that preceded the formation of our solar system.

By stretching the capabilities of our largest telescopes, and by constructing even larger instruments on Earth and in space, we may be able to see galaxies so far away that the light reaching us will tell us what they looked like when the universe was young. Spectra of distant quasars may give us hints about chemical abundances at still earlier times.

Complex, confusing, and difficult? Certainly! — and the difficulties will surely tax the endurance of observers and theoreticians for many years to come. But the reward will be a better understanding of the origin of the substances we are made of.

Gregory Shields is an associate professor of astronomy at the University of Texas at Austin. His research interests include emission lines and energy sources for quasars as well as the chemical composition of galaxies and nebulae. He co-authored "Why All the Fuss about Quasars?" for the October 1980 issue of ASTRONOMY.

The Changing Immutability of the Heavens

by William Siletti

As it has done for the past four billion years, the Sun hangs low in an autumnal sky, relentlessly descending to the western horizon. Its paling rays cast soft shadows silhouetting the landscape. At last the moment of sunset arrives. The crimson of twilight cools; the sky darkens and becomes blue, then deep violet. The first bright stars cast their pale glow on the Earth. Night has begun.

Soon, less-bright stars appear until even the dimmest stars shine, and the sky is transformed into thousands of shimmering points of light.

To the eyes and minds of humans, stars appear to congregate into distinct patterns. These shapes were familiar even to ancient peoples. They depicted the great battle between Orion the Hunter and Taurus the Bull. They pantomimed the ceaseless struggle between Cetus the Sea Monster and Perseus the Hero for the beautiful maiden Andromeda. They pictured the conceit and consequent humility of Queen Cassiopeia, and re-enacted the endless chase of the American Indians in pursuit of the Great Bear.

The motions of the stars, too, occupied an important place in the human mind. The Mesopotamians became the world's first astrologers; the Hindus divided the celestial sphere into various *nakshatras,* which correspond roughly to our zodiacal constellations. The Egyptians recognized the constancy of the annual rising of the Dog Star, Sirius, and based their agricultural calendar on it. The ancient inhabitants of Britain assembled a stone observatory on the Salisbury Plain — Stonehenge — that still quite accurately locates the rising and setting positions of the Sun and Moon for various times of the year. To the ancients, the stars seemed reliable, unchanging, immutable in their paths across the heavens.

Let us retrace astronomical history to a major discovery: a star catalog made by the Greek philosopher Hipparchus, a member of the Alexandrian school. In 134 B.C., the discovery of a new star in Scorpius — in itself an important event — prompted Hipparchus to compile a new star catalog. From his observatory on the island of Rhodes, he measured the positions of objects in the sky as accurately as possible, constructing one of the first systematic catalogs of the stars — a compilation containing approximately 1100 entries.

Hipparchus determined celestial coordinates for each star and assigned a brightness value, or magnitude, ranging from 1 to 6 — brightest to faintest. He then compared his measurements with those of Timocharis and Aristyllus, made a century and a half earlier, and discovered that the celestial longitudes of all the stars seemed about two degrees greater in his catalog than in the earlier one. Over the century and a half separating the catalogs, the North Celestial Pole had apparently shifted. Hipparchus calculated that the vernal equinox was shifting westward by about 1.4° per century, or about 45 seconds of arc per year.

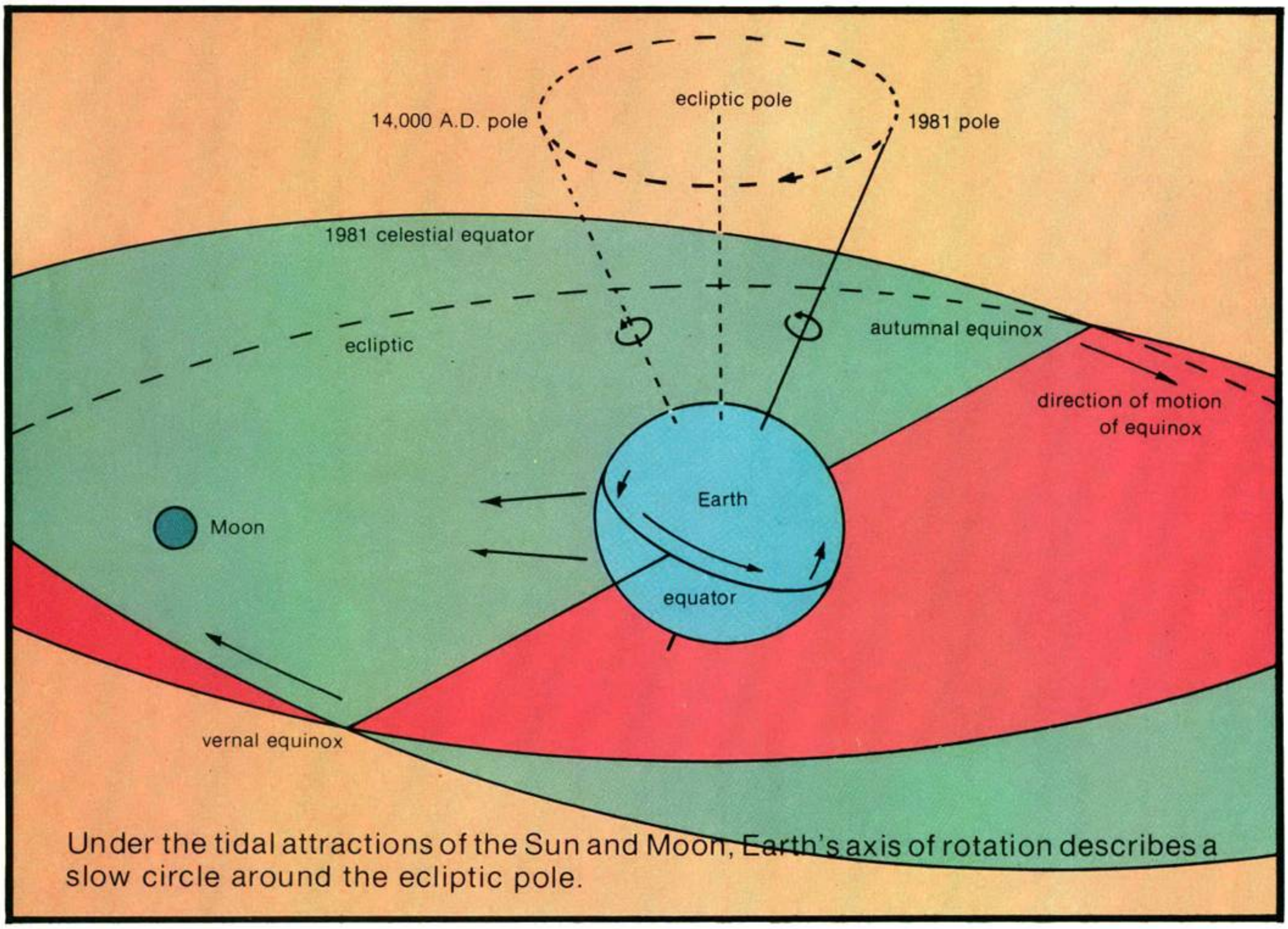
How enthralling and disturbing this must have been to Hipparchus! The heavens had been considered constant, unchanging. In fact, this immutability of the heavens was probably one of the few sources of tranquility in the Hellenic world during those chaotic times. And now, the equinox that dictated the passage of winter and the advent of the planting season had moved.

This slow-moving, westward drift is called *precession of the equinoxes,* and it was the discrepancy in the longitudes of two stars in particular, Regulus in Leo and Spica in Virgo, which led to Hipparchus' discovery of this phenomenon. The current value for the precession of the equinoxes is 50.23" per year, quite close to Hipparchus' value. It requires approximately 25,800 years for one complete cycle. If we calculate back over the 2000 years since Hipparchus' time, we find the vernal equinox was once located about 28° east of its present position in Pisces. During the time of Hipparchus, the equinox was in Aries, which is logical since even now the equinox is sometimes called "the first point of Aries."

Wobbles and Bulges

Nicholas Copernicus was the first person to recognize precession as the slow wobbling of the Earth's axis around the perpendicular to the Earth's orbital plane. And Sir Isaac Newton was the first to explain its cause in modern terms. Newton noted that the rotation of the Earth must cause it to deform slightly into an oblate spheroid. Thus Earth is not perfectly spherical — the equatorial diameter is 27 miles greater than the polar diameter. Newton also recognized that the *pull of the Sun and Moon* upon this equatorial bulge causes precession.

The plane of the Earth's equator, and therefore



Under the tidal attractions of the Sun and Moon, Earth's axis of rotation describes a slow circle around the ecliptic pole.

the plane of the equatorial bulge, is inclined 23.5° to the ecliptic, the plane of Earth's orbit. The plane of Earth's orbit is in turn tipped about 5° to the plane of the Moon's orbit. Gravitational pull by the Sun and the Moon on the Earth causes the tides on the oceans, and also pulls on the equatorial bulge of the Earth.

The Sun tends to pull the Earth's equatorial bulge toward the plane of the ecliptic, while the Moon attempts to pull the bulge into the plane of the Moon's orbit, which is fairly close to the ecliptic. These two forces tend to pull the Earth's axis into a direction almost perpendicular to the ecliptic plane — in a very nearly vertical orientation. Like a spinning top, the Earth resists these forces and compensates by precessing at a solid angle of 47° at the apex of motion. This precessional motion is very slow, requiring approximately 25,800 years to complete one cycle — and over this period of time, the north star of the heavens changes. Presently Polaris, in Ursa Minor, lies nearest the pole.

During the time of the pyramid-building Egyptians, Thuban, the alpha star in the constellation Draco, appeared near the pole. Thus the pyramid at Cheops was centered on the "north star," but when it was built, the north star was Thuban, not Polaris. As precession continues, the pole star will change again. By about 7500 A.D., it will be Alpha Cephei. And 12,000 years from now in 14,000 A.D., Vega, in Lyra, will occupy the northern celestial throne.

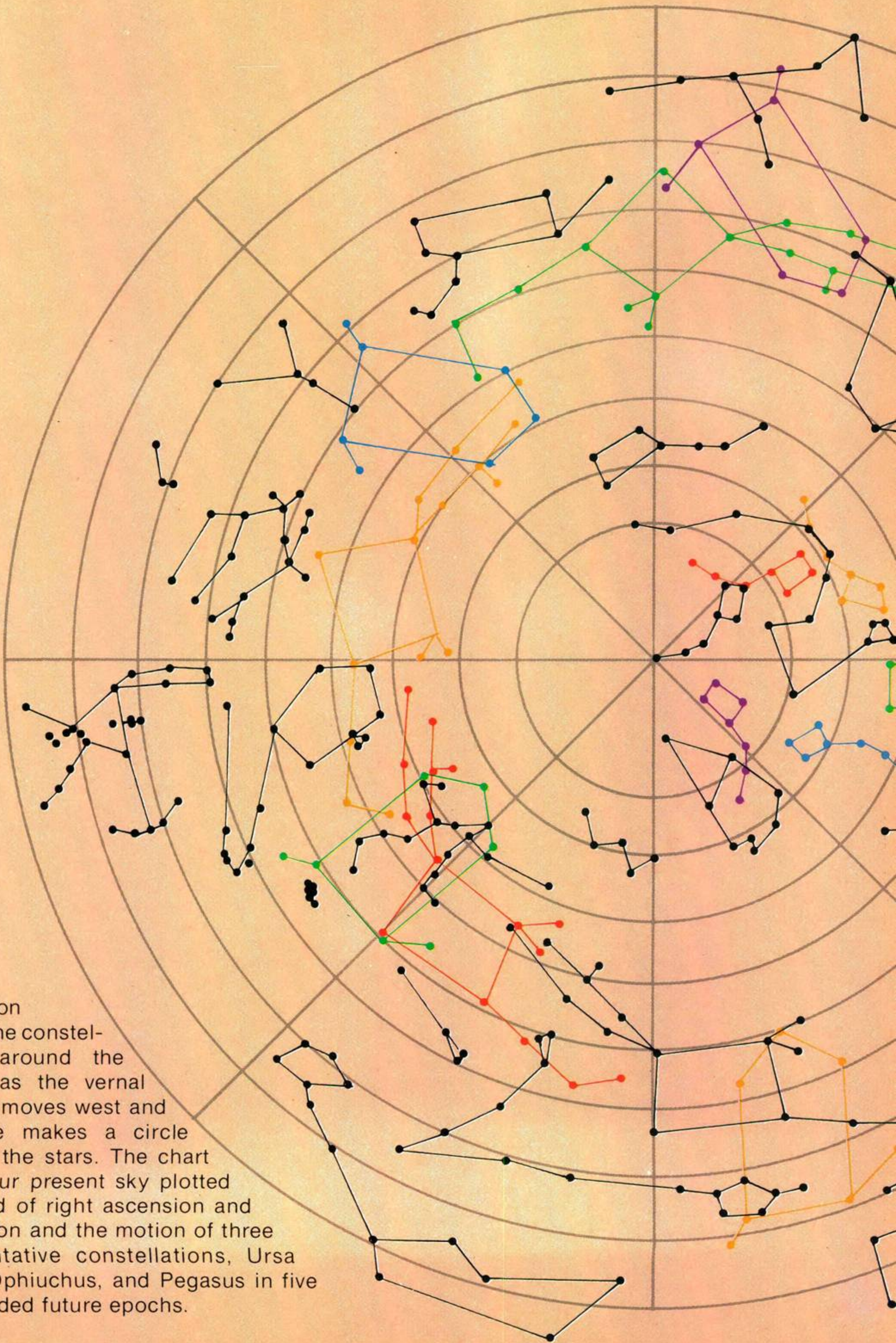
But why do the equinoxes shift? As the pole moves around its circle in the sky, the celestial equator — an imaginary circle 90° from either pole — also moves. Since the positions of the equinoxes are defined by the intersection of the equator with the ecliptic, as the equator moves, the intersection will drift along the ecliptic and cause the equinoxes to move.

The Changing Constellations

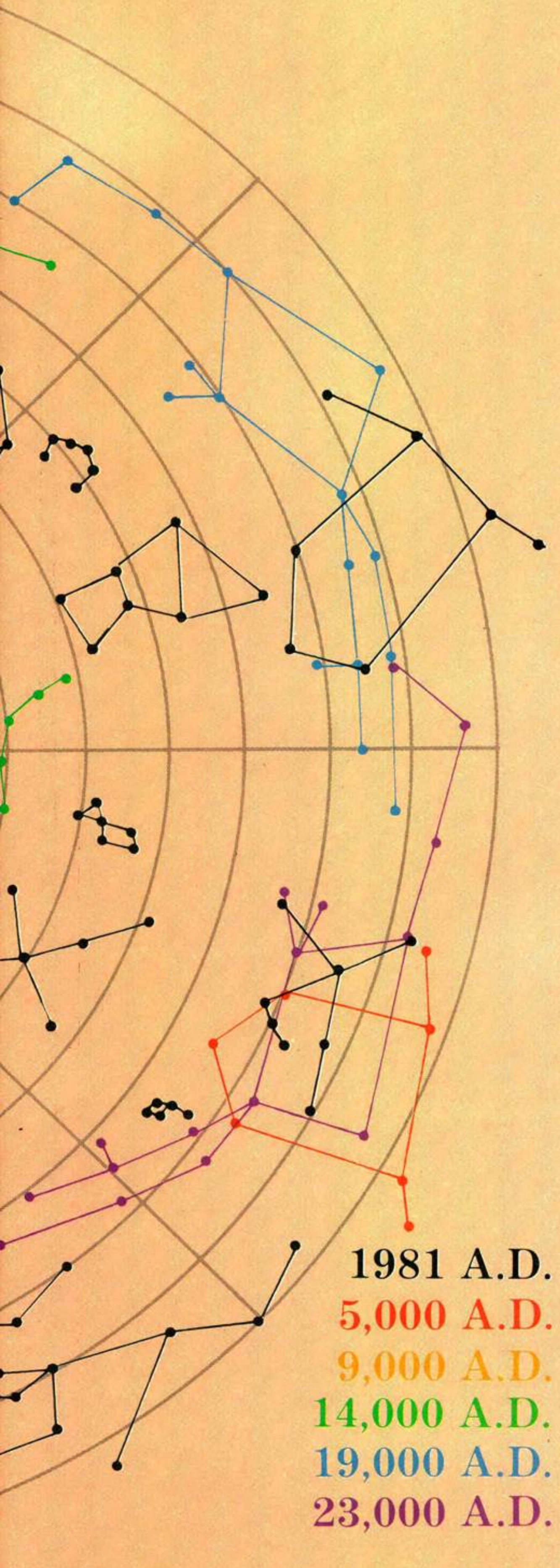
Of course, if any star on the celestial sphere appears to shift because of precession, all stars must. Thus, the positions of the constellations in the sky also change. Constellations that are circumpolar now — those that circle the pole and never set — will not be circumpolar in the future. And some constellations that cannot be seen now will be visible centuries from now.

How did the sky look to people living in the past, and how will it look to those in the future? We obviously cannot ask William the Conqueror or Hammurabi, nor can we query those not yet born. However, it is possible to explore the past and future skies by calculating the effects of precession. Of course, proper motion — the actual motion of stars across the sky — causes a few slight changes over a 12,000 year interval, but no changes drastic enough to alter the shapes of the constellations. The only prominent star which would be affected is Arcturus, in Bootes. (See "Look Who's Moving Into Our Neighborhood," ASTRONOMY, April 1979 for more about proper motion.) Over long periods of time, however, such effects do indeed become significant.

Let's move ahead in time to 5000 A.D., when the



Precession swings the constellations around the ecliptic as the vernal equinox moves west and the pole makes a circle through the stars. The chart shows our present sky plotted on a grid of right ascension and declination and the motion of three representative constellations, Ursa Minor, Ophiuchus, and Pegasus in five color-coded future epochs.



pole will be located in Cepheus. The southern pole will lie in Carina. Cetus will rise much higher in the sky than it does now, and Ursa Major will become a seasonal (rather than circumpolar) constellation. Capricornus will host the vernal equinox in this era, Aquarius having relinquished the site about 500 years earlier.

In 9000 A.D., the Milky Way will be continuously present in the night sky, with the bright parts in Cygnus very near the pole. Arcturus will lie very close to the celestial equator, as will Castor and Pollux in Gemini, Aldebaran in Taurus, and Mira, the famous variable star in Cetus.

By 14,000 A.D., the sky will reach its maximum difference. Brilliant Vega will then be the pole star, and the center of the Milky Way, in Scorpius and Sagittarius, will ride high in our northern skies.

Further changes will greet the observer of 19,000 A.D.: Cepheus and Cassiopeia will no longer be circumpolar, although Hercules and Bootes will. In fact, Hercules and Ophiuchus will be on opposite sides of the zenith for observers at the latitude of New York City. This will undoubtedly be a welcome relief for the mythical figure of Hercules, since he'll be standing on his feet instead of in his present position — on his head.

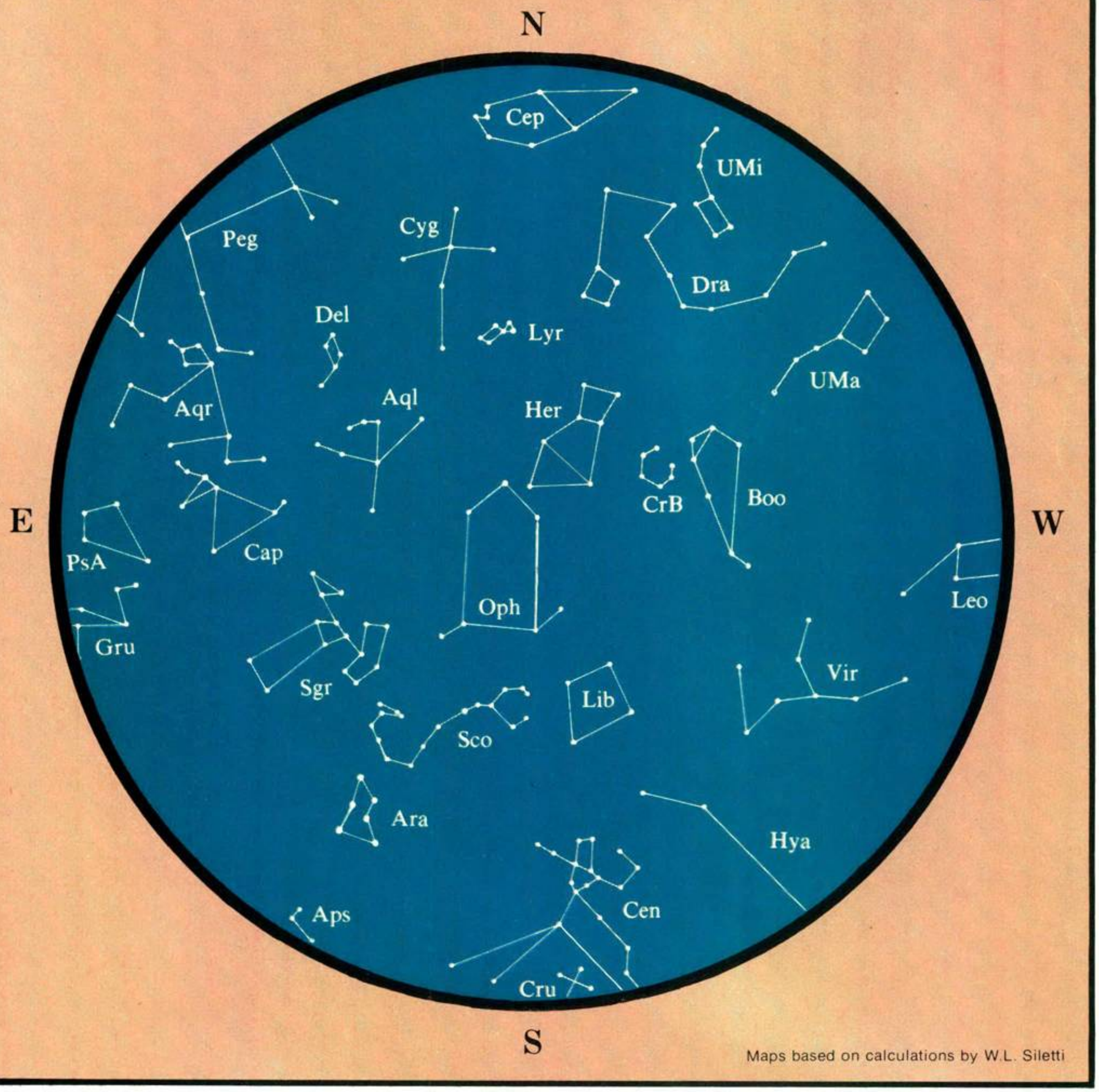
By 23,000 A.D., Thuban has once again taken over the controls as the pole star. The sky of the 231st century will probably appear much the same as it did above the pyramid builders of Egypt. Centaurus will be prominent, as will Crux. But in general the skies by this time are becoming more nearly like our familiar 20th century heavens as precession brings the sky around to full circle. By 28,000, our current skies will once again swing overhead, with only a few changes due to proper motion making the heavens seem strange to us.

September: 14,000 A.D.

Let us imagine the passage of stars during the course of a night in mid-September, 14,000 A.D. — an epoch that a modern constellation watcher would find most bizarre. Imagine the Sun has set, twilight has ended, and the stars are beginning to shine brightly. How the constellations have changed! Brilliant Vega blazes all night in the north — this epoch's Polaris. Lyra, Cygnus, Hercules, and Corona Borealis are now circumpolar, with Draco, Cassiopeia, and Ursa Minor nearly so. In the east, Aquila the Eagle is rising. Andromeda has set, soon to be followed by Perseus. Ursa Major is almost overhead. In the south, we see Leo about halfway to zenith, while Auriga and Gemini are setting in the southwest.

By midnight, Cepheus is nearing the horizon in the north, although it will not set completely. Cassiopeia is about ready to set. Scorpius has just risen in the east and Sagittarius is rising in the northeast! Bootes and Corona Borealis are overhead while Virgo, in the spring equinox position, is due south — about 45° above the horizon. Cancer the Crab has set and Leo is low. Centaurus has risen, and following him is Crux, the Southern Cross — both visible in this epoch as far north as New York City and Cleveland.

By 3 a.m., Ophiuchus is overhead, and Capricornus and Aquarius have risen. Both Dippers are setting in the northwest. In the southeast, Grus and Piscis Austrinus are visible on the horizon, and


The Fall Sky for September 15, 14,000 A.D. Midnight

Maps based on calculations by W.L. Siletti

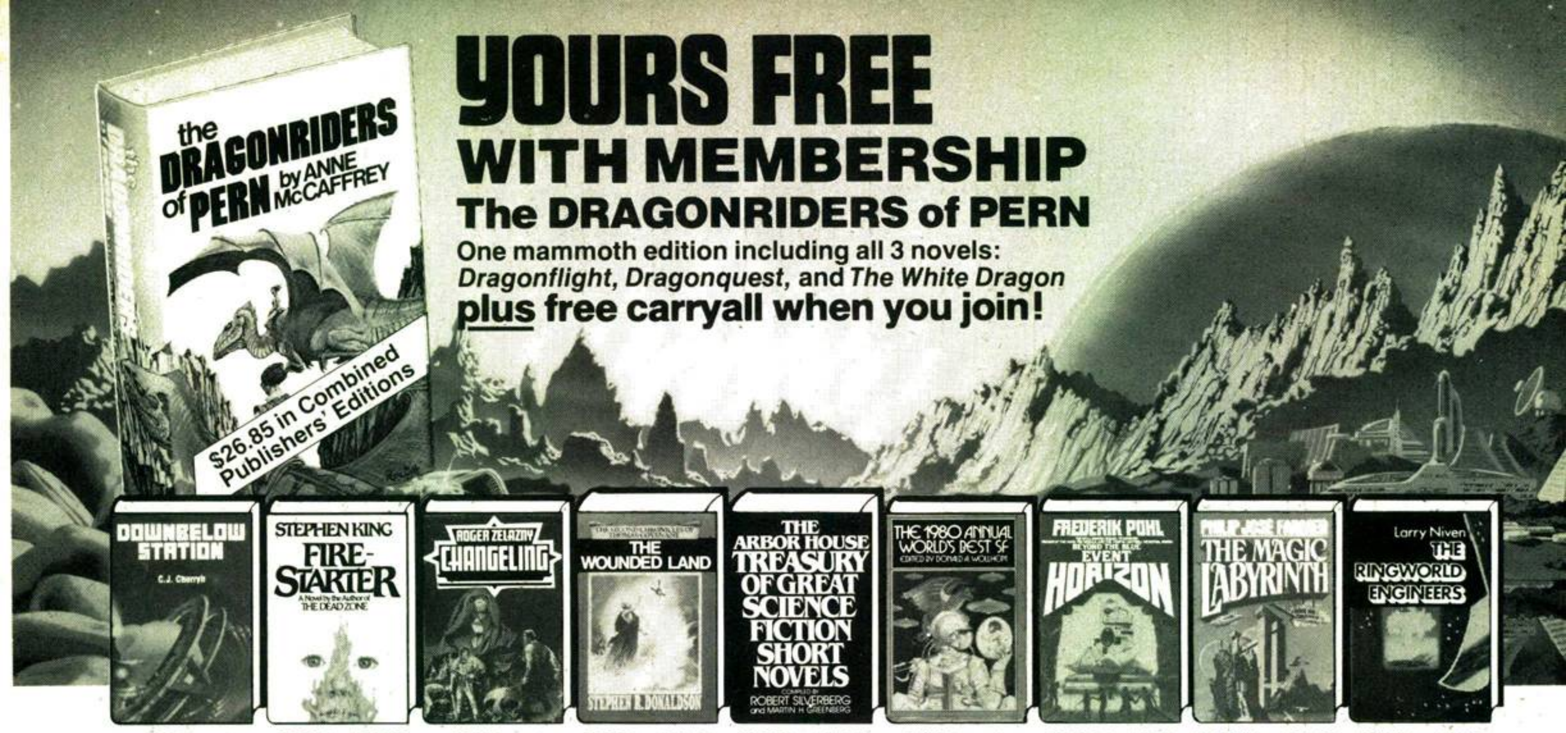
Leo is disappearing in the west. Crux has risen to its greatest elevation above the southern horizon (about 10°), and Alpha Centauri, the nearest star, lies about 15° above the horizon. The Milky Way crosses the celestial sphere in a majestic arc — from Cepheus and Cygnus in the north through the galactic center to Crux and Centaurus in the south.

As the sky brightens in anticipation of sunrise, we glimpse the bright stars of Sagittarius culminating at about the same altitude that Gemini does in 1981. In the southwest, Centaurus and Crux set, and Octans the Octant and Apus the Bird of Paradise are due south, just a few degrees from the horizon. The little constellation Toucan, with the Small Magellanic Cloud, is almost fully visible.

Have we missed anything? Yes — where are Orion, Taurus, and Canis Major? Taurus has now become a summer constellation and does not rise very high in the sky. As for Orion: alas, we are denied his magnificence in 14,000 A.D. Betelgeuse culminates a mere 15° above the horizon, and the Orion Nebula will just scrape the horizon. Brilliant Rigel will not rise at all — it is a southern star in this period. Canis Major will fare even worse — it will be totally south circumpolar in this epoch. One wonders what the Egyptians of this period would do at planting time — their dog star never rising.

Although it appears there will be a more brilliant northern sky in 14,000, it will be at the expense of some of our dearest friends. Even in astronomy, you can't get something for nothing.

William Siletti taught physics and mathematics for eight years in Brooklyn, New York and currently is working at the American Institute of Physics in New York City. He is an avid amateur astronomer — which explains his interest in the skies of the future.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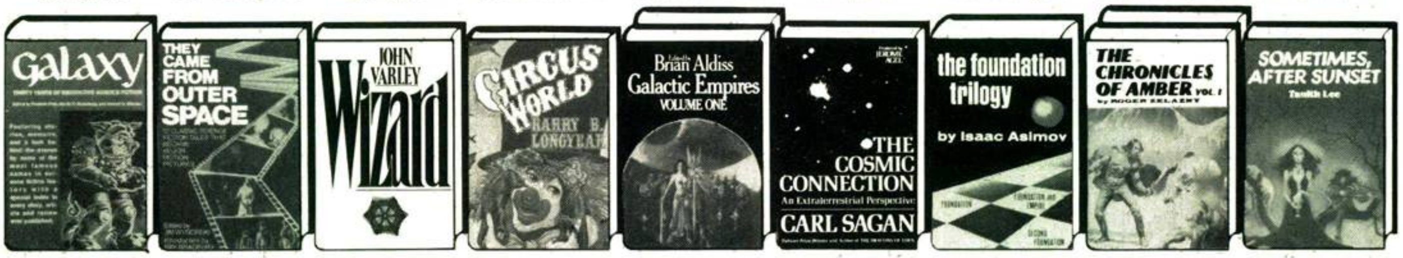
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ASTRONOMY
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Jay U. Gunter

Dr. J. U. Gunter is the publisher of the bi-monthly newsletter, **Tonight's Asteroids**. *He calls it "a project in amateur astronomy"; others have called it a labor of love. Anyone can subscribe to this useful bulletin because all it costs is a stamped, self-addressed envelope sent to 1411 North Mangum, Durham, NC 27701.*

In April 1980, a fitting honor was bestowed on this dedicated "asteroider": the **Minor Planet Circular** *announced an asteroid named in his honor, 2136 Jugta. Thus for as long as astronomical records are kept, the initials J.U.G. will be linked with the initials of his literary creation — T.A.*

The citation states that "through his free bi-monthly newsletter, Gunter has sparked wide interest in minor planets and has inspired numerous amateur and several professional astronomers to study these objects."

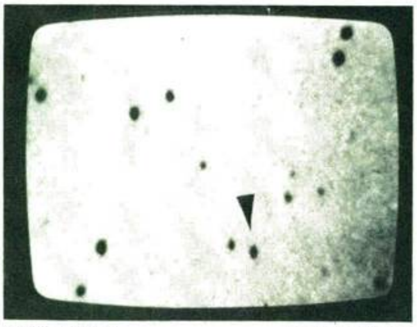
ASTRO: How long, Dr. Gunter, have you been involved with astronomy?

JUG: Twelve years. I became interested in it when I saw a course advertised by the Morehead Planetarium in Chapel Hill, North Carolina. So my wife Elizabeth and I signed up for the six weeks. We had good instruction in the planetarium; that's how I started.

ASTRO: Twelve years seems an extremely short time in terms of what you have achieved. What turned you in the direction of asteroids?

JUG: In the very first course we had, and in each of the three I took after the first, they gave us a copy of the Royal Astronomical Society of Canada's *Observer's Handbook* for 1968. In it, there were charts of the "big four" asteroids, Ceres, Pallas, Juno and Vesta. All of them were in season at that time or shortly thereafter, so I went out in my backyard with my binoculars and started checking on Ceres. I found it without any trouble.

Then I drew up a little handout sheet for our class of twenty or twenty-five people. It showed a diagram of the constellation which the asteroid was in and demonstrated just how to find it. Several of our classmates succeeded in finding it, which in turn got me more interested in asteroids.



2136 JUGTA by Ben Mayer

ASTRO: Your work encourages me as an amateur. When I saw my first copy of *Tonight's Asteroids* I thought it was published by a professional astronomer who had been doing this kind of work all his life. But it's really the relatively recent achievement of a dedicated amateur. At what point did the single sheet handout take wing?

JUG: As soon as I acquired my first telescope and had more "power" to work with. Every time a chart for an asteroid was published in one of the astronomical publications, I would go out and attempt to find it — and I usually succeeded. Soon I wanted more information about asteroids than I was getting. When I learned that I could get a book with the ephemerides of the asteroids for the year, I ordered it and found a much greater number of them. When I had gotten up to about thirty-five or forty, I decided to submit a column to some amateur astronomy publications — a chart or two with some pertinent information about the objects and their discoverers.

ASTRO: Did you always use Hans Vehrenberg's star atlas photos as your underlying charts?

JUG: For star fields I used the *Atlas Eclipticalis* and then later switched to the excellent Vehrenberg charts. I have never met Dr. Vehrenberg but I have written to him. I asked him for permission to use his material for starfields in the preparation of my charts and he promptly granted it. He has since indicated that the increased popularity of his atlas was due in part to my use of it for this project.

ASTRO: Do you, yourself, look for the asteroids which you write up in your columns?

JUG: I did back in the earlier days, but my backyard and surroundings have so much light pollution that I cannot do nearly as much observing as I used to and as I'd like to.

ASTRO: In *T.A.* you feature asteroids which will be in the sky soon after the newsletter reaches your readers. Do you have magnitude criteria?

JUG: Yes. The magnitudes, of course, are stated on the charts. I don't publish many that are fainter than visual magnitude 11.5. In the exceptions, I go to 12.0. All of these lie within the range of a 6" reflector under a good sky.

ASTRO: You always include copious notes about each asteroid. How do you come by this valuable

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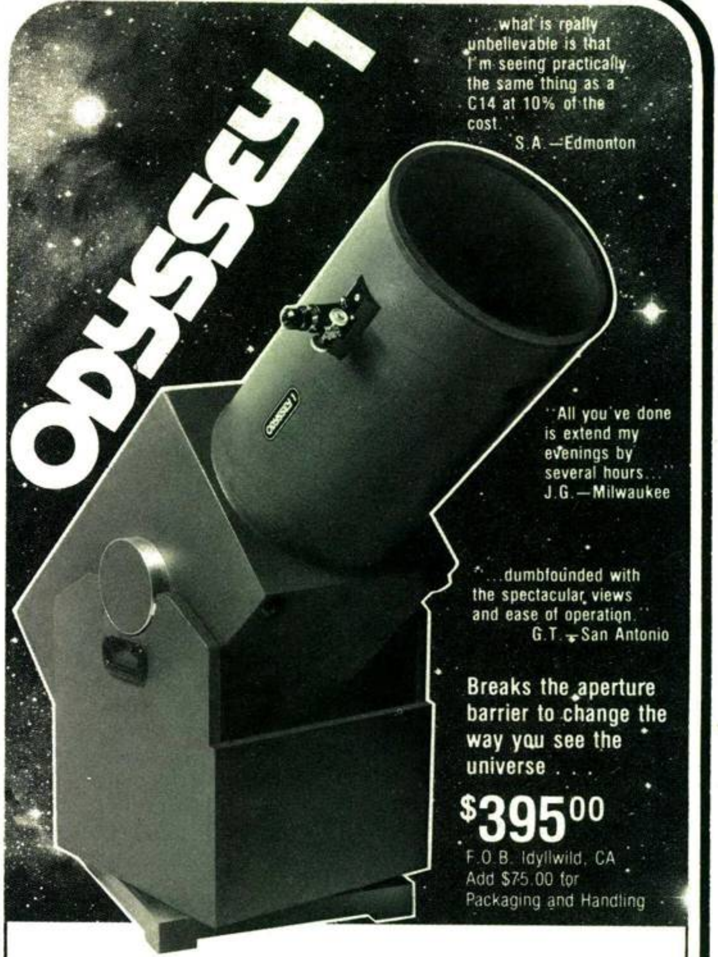

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information?

JUG: Over the years I have accumulated a considerable amount from old astronomy textbooks and old issues of astronomy journals, some dating from the nineteenth century. A friend of mine, June LoGuirato, who lives near Washington, D.C., sends me some information of historical value for each issue. She has access to libraries there — including the one at the U.S. Naval Observatory and the Library of Congress.

ASTRO: Over the years you must have sent your newsletter to hundreds of people. Would you venture a guess at how many subscribers you have had?

JUG: The total number is well over 1000. The present number is over five hundred. I have 550 to 600 copies printed. *T.A.* consists of eight pages of charts and text.

...others have called it a labor of love...

Since my subscribers send self-addressed stamped envelopes, I don't worry about addressing and postage. My wife is a great help in collating, folding and envelope stuffing. She also helps with general clerical matters. We have over 60 overseas subscribers and about twenty in Canada.

ASTRO: You have just been shown the ultimate recognition — having an asteroid named after you and your publication. Can you tell us how this came about?

JUG: This is something I never thought would happen to me because there are so many people who deserved this honor more. For some years now I have been a friend of Dr. Brian Marsden who is head of the Central Bureau for Astronomical Telegrams and director of the Minor Planet Center. He was one of the movers, as was Eric Fogelin, a longtime subscriber who suggested the name "JUGTA."

ASTRO: When was "JUGTA" discovered?

JUG: It was discovered in 1933 and was given the designation 1933 OC. In subsequent years it was observed again a number of times until finally there were enough observations to compute an orbit and to give it a permanent number and name.

ASTRO: Have you ever thought of recruiting somebody else to help you or even to take over *Tonight's Asteroids* if you should get tired of putting it together six times a year?

JUG: I am afraid it will be hard to find someone who would be willing to spend as much time on it as I do. I enjoy what I am doing because anyone who searches for asteroids learns a great deal about the sky and about the use of a telescope.

There is a great satisfaction that comes from the positive identification of a unit of the solar system only 100 miles in diameter and a hundred million or so miles away. So you see, it is with genuine enthusiasm that I recommend the asteroids to every amateur astronomer. One of the greatest joys is the incentive asteroids afford for getting out each night and having a look at the splendors of the sky.

Ben Mayer
Los Angeles, CA

Bruce Margon and SS-433

Though he did not actually discover SS-433, Dr. Bruce Margon was the first astronomer to recognize and formally point out the remarkable strangeness of this stellar object. Along with theoretician Jonathan Katz and fellow astronomer George Abell, Margon also proposed the most widely-accepted model for the nature of SS-433 (see ASTRONOMY, July 1980).

At the time, 33-year-old Margon was a member of the astronomy department at UCLA. He recently moved to Seattle, where he holds a position in the astronomy department at the University of Washington. He took a few minutes of his busy schedule to chat with ASTRONOMY about SS-433 and some of his other irons in the fire.

ASTRO: What new things — if any — have you and others discovered about that curious object called SS-433?

BM: There are no enormous advances on the optical front. Mostly my bunch of people is continuing to obtain spectra as frequently as possible. We are now looking for more subtle effects in the kinematic model. As the volume of data increases we'll compare it with other predictions by more obscure models, and see if they fit better or not.

But most of the exciting new observations, as far as I'm concerned, are going on in the radio region of the spectrum.

ASTRO: Using Very Long Baseline Interferometry?

BM: Yes. Some experiments are beginning to get interesting results in resolving the source in SS-433 and seeing time variability. It turns out, by the way, that the optimum baseline you want for radio observations of SS-433 is relatively short — about 100 kilometers. VLBI people are used to working with much longer baselines of course — but that method over-resolves the source and does not give you much observation time.

ASTRO: And what's being seen?

BM: Well, what these guys are beginning to see, slowly and quite painfully, is that there seems to be a jet-like structure, and it seems to be rotating — possibly with a 164-day period — but it's a little too early to say that just yet.

ASTRO: Is the radio jet coincident with the jets of matter proposed in your kinematic model?

BM: Well, we're talking about something that's very, very small — only a couple hundred milli-arc-seconds, so there's no way of saying. What's important is that the ephemeris of the rotation seems compatible with the optical ephemeris. Right now we only have six or seven data points, so we can't say for sure that this is the same thing as SS-433. However, I think we can say that the writing seems to be on the wall — that it may very well be the same thing as SS-433.

ASTRO: You and others have said it looks like SS-433 is a stage in the evolution of a binary X-ray star.

BM: That's probably right. But we can't conclude that for sure until we find a second object like SS-433. If we only have one, it could be some kind of fluke.

ASTRO: But if it has a really short lifetime, it seems you could be right about it being an evolutionary stage — and yet there'd be only one in the galaxy at any one time.

BM: Well, SS-433 is luminous enough so that we'd have no trouble finding other SS-433s in the Andromeda Galaxy or in the Magellanic Clouds. It would be about 14th magnitude in the Magellanic Clouds, and 18th magnitude in the Andromeda Galaxy. If you knew where to look, it would be easy to observe. We've already looked in the Magellanic Clouds — using some appropriate trickery — and we haven't found one.

Until someone does find a second SS-433, or something that looks even remotely like it, it's an unverified assumption that SS-433 is a common transient stage in the evolution of a binary X-ray star.

ASTRO: Well, all in all, it seems as if what you've been doing is similar

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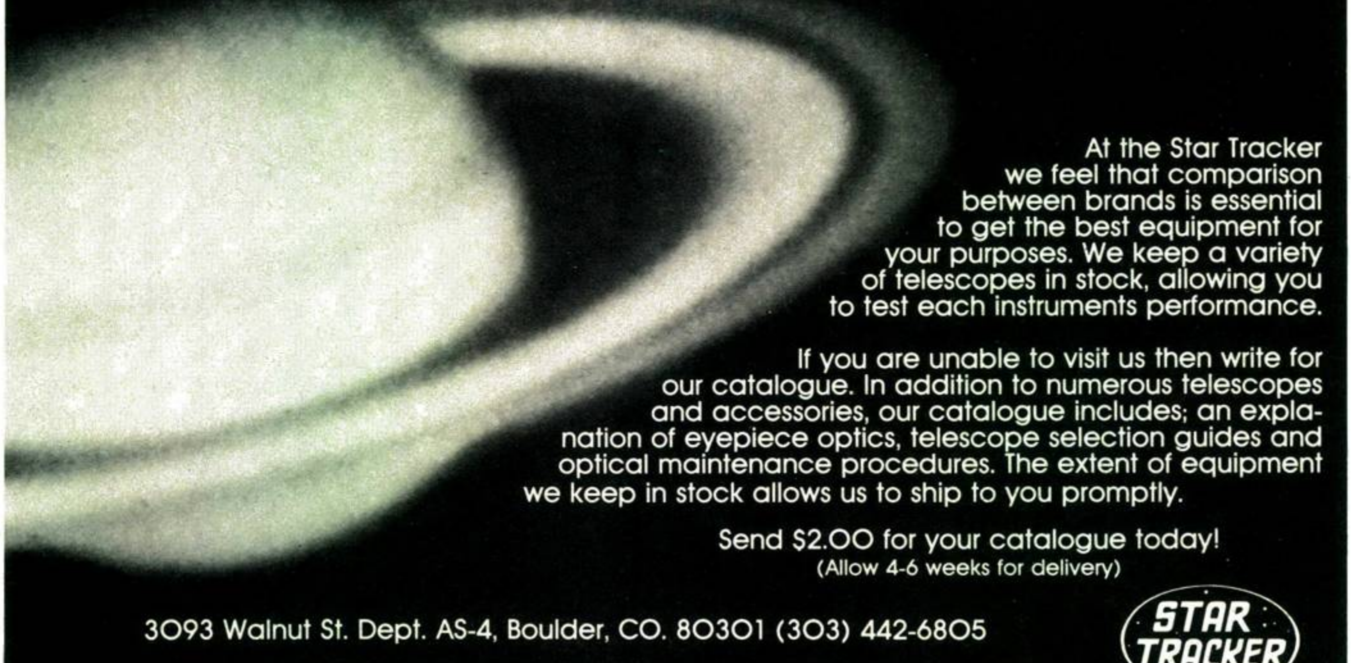

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to putting together a complex jigsaw puzzle.

BM: (laughs) Certainly for the first year there were a lot of false starts, let's put it that way! Yet, if you look at the history of the discovery of most unusual objects, you find that it works in a fairly similar way: numerous false starts, and then suddenly a rush of understanding.

ASTRO: What kinds of things are you working on now?

BM: Well, I have several different projects — short-term, medium-term and long-term.

In the short-term I'm still very much involved in the optical observation of X-ray source counterparts...

ASTRO: SS-433?

BM: No, not so much SS-433 any more, because I feel that the contribution from the kind of work that we can do is beginning to tail off. We now have 250 nights of data. It's going to be twice as hard to get 500 nights of data — but not twice as valuable.

I've gotten into a new problem which looks extremely promising. It's the optical identification of what are called *serendipitous X-ray sources*, found by the Einstein Observatory. A very large number of the pictures the X-ray telescope takes not only show X-rays from the object it's pointed at, but also from objects at the corners of the pictures — accidental observations. We refer to those as serendipitous sources because they're found by accident.

And there are huge numbers of them, larger numbers than anyone expected. For each planned observation made, there are one, two, three, up to a half-dozen unplanned observations of previously unknown sources as well.

So we ask: "What are these serendipitous sources? Do they have optical counterparts?" Several different groups are working on this, but I think mine has a head start.

ASTRO: And what do these serendipitous sources turn out to be?

BM: Ahh! Well, most of them are previously uncataloged quasars — not an enormous surprise. Various scientists suggested X-rays as a good way to discover new quasars. The surprise is the frequency and ease with which we're finding them.

I mean, we're finding huge numbers. Over 40 new quasars in just a few weeks of observation! X-ray emission is the most unbiased way of discovering new quasars. Other techniques for finding quasars find only certain kinds — whether you use radio, strange colors, or so on. This technique is going to be extremely useful for compiling an unbiased sample of quasars to answer all kinds of questions.

ASTRO: Why serendipitous objects? How did you get interested in them?

BM: Well, actually I was looking for other objects like SS-433. But in fact we find very, very few stars with this type of emission — almost everything is extragalactic.

ASTRO: What about your medium-term plans?

BM: In the medium-term, I'm a co-investigator for one of the focal plane instruments on the Space Telescope. When it's launched, it will carry five separate detectors at its focal point. One is being made by a consortium of six university scientists. I am one of them. That project has been underway for two and a half years now, and we're about halfway through as far as constructing it.

ASTRO: It's the faint object spectrograph, isn't it?

BM: Yes — one of the two spectrographs on the Space Telescope. The principal investigator is Richard Harms of the University of California at San Diego. The rest of us are scattered all over the country.

We refer to those as serendipitous sources because they're found by accident.

Our job is to design, construct, calibrate, fly, and test this instrument — and make software for it. In turn, we have exclusive use of it for a short period of time in the early lifetime of the Space Telescope. It's an enormous undertaking that requires a fair investment of time in exceedingly non-astronomical tasks — lots of meetings and documents.

ASTRO: So anyone who wants to get a spectrum of anything with the Space Telescope will have to use this instrument?

BM: It will take spectra of extremely faint objects both in the ultraviolet and the visible regions of the spectrum.

ASTRO: It could be used for anything, then.

BM: Sure, that's right. I'm sure some people will use it for planetary astronomy, others for stellar astronomy, and still others for extragalactic astronomy — anything that needs a spectrum.

ASTRO: That leaves us with long-term projects — what are they?

BM: I'm working on one rather longer-range, somewhat speculative project that I have high hopes for. It involves a newly-constructed network of Air Force telescopes called GEODSS — for Ground-based Electro-Optical Deep Space Surveillance System. (See "AstroNews," ASTRONOMY, May 1981.) It's a 15-telescope system designed to track satellites. I've proposed to the National Science Foundation to construct, with TRW, a set of auxiliary instruments to hang on the telescopes. They could retain the data that GEODSS acquires on the brightness of stars — each telescope will take several thousand pictures a night. But they're looking for moving objects so they throw away everything that doesn't move, and that's almost everything — most important to us, the starfields.

Our instruments would retain this data and we'd end up with a digital data bank of information on the brightness of celestial objects. You could query via computer for any object in the sky — and the coverage of GEODSS is such that nearly every point on the celestial sphere will be covered several times a night.

When somebody found something interesting, they could come to us at the data bank and ask what the brightness of the object has been in the past, and how it's varied. The 13-day period of SS-433 could have been found this way without doing any extra observations.

ASTRO: How will this data be stored after you rescue it from the Air Force?

BM: We're proposing laser-written television video disks to store it. We estimate that 15 years of nightly data from GEODSS could fit in a four-drawer filing cabinet.

These days, if you want to know how an object's brightness has varied in the past, you have to go to a place like Harvard's photographic plate stacks. And maybe you'll get 30 or 40 random measurements spread over a hundred years. This way, you'd get one or two measurements per night for the duration of the GEODSS.

ASTRO: How does the Air Force feel about this?

BM: Oh, the Air Force has been extremely cooperative. They know this doesn't affect their telescopes, where they're pointed, or their mission. And the taxpayer pays nothing for the extra data we get, because they've already paid for the GEODSS system — we're just rescuing data the Air Force can't use. And besides, the Air Force is interested in producing good science, *too*.

Joel Davis
Olympia, WA

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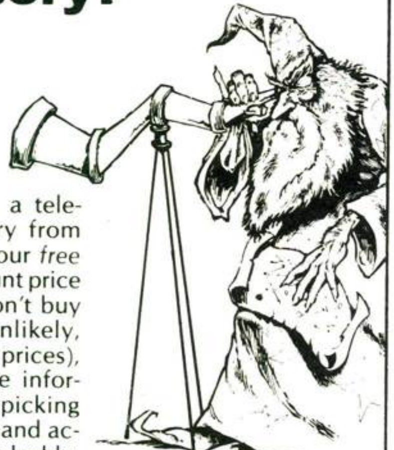

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eye
on the
sky

venus returns as the evening star

by
Fred Schaaf

the wanderers

Last month **Venus** became clearly visible in the evening sky for the first time since June 1980. With a little more altitude this month, it makes its return as the Evening Star — very prominent after sunset. Our "sister" planet also shares in a notable conjunction with a faint **Mercury** on June 9.

The difference in time of setting between the Sun and Venus grows from about 70 to about 90 minutes during June, but this period will then remain about the same for the rest of the summer. Not until leaves begin to turn color at the beginning of autumn will the separation lengthen and the brilliant planet escape from twilight. Last year's evening apparition of Venus was one of the best possible (with Venus setting a maximum of over 4 hours after the Sun) and will not be equaled until 1988. The current apparition will be a fair one, with Venus setting over 3 hours after the Sun in December.

On the evenings of June 8 and 9, United States observers will have their best views of Venus about 2° north of Mercury (at the actual moment of conjunction they are 1.7° apart). While Venus will be at magnitude -3.3 (virtually its faintest), Mercury shines at only +1.8, so skies will have to be quite clear for a good naked-eye view. This should be one of the last nights Mercury can be glimpsed before it moves back too close to the Sun — the elongation (distance from the Sun) of the planets during the conjunction is 17°.

We seldom stop to think that Mercury can, at times, be the closest planet to Earth, but that is the case this month. While Mercury is swooping toward inferior conjunction (almost directly between Earth and Sun) on June 21, Venus is on the far side of its orbit from us. On the night of June 16-17 Venus is at perihelion just one hour before Mercury is at aphelion. Since it is only a few days later that Mercury pulls even with Earth in their race around their orbits, Mercury is just about the closest it can ever be to us on June 20: 0.5546 A.U. (1 Astronomical Unit is the average Earth-Sun distance). During their conjunction on the 9th, little Mercury actually has a larger apparent diameter in telescopes than Venus.

On the evening of the 3rd, a **Moon** slightly more than 1½ days old can be found several degrees south of Mercury and Venus. Venus has another fascinating conjunction on June 6, passing almost centrally through the star cluster M-35 in the feet of Gemini. It is unfortunate that the objects will be in a bright twilight sky — even good binoculars may not produce a view of the large 5th magnitude cluster.

Just one planet now hangs in the morning sky. **Mars** rises 90 minutes before the Sun by the end of June, but it's inconspicuous, hidden in Taurus with a magnitude of only about 1.6. In the middle of the month, the red planet will be well to the north of the considerably brighter and also red Aldebaran in the bright morning twilight.

As was the case in the past months, our most conspicuous planets for June are the giants **Jupiter** and **Saturn**, well up in the southwest as darkness finally falls after these longest days of the year. Jupiter is now about equal to Sirius in brightness, while Saturn is comparable to Spica. Saturn resumes direct (eastward) motion on June 6 with Jupiter again in pursuit and closing the gap. Saturn pulls very close to Eta (η) Virginis by month's end and both of these planets are then at 90° from the Sun — a position known as eastern quadrature. The Moon is near these planets on June 7.

Next month, Jupiter will overtake Saturn for the last time in their **Great Conjunction**. But a panoramic scan of the southwest early on June evenings shows us that still later in the summer we are in for another and larger-scale spectacle. Can you foresee what is going to happen?

Before we look at the answer, let us go briefly from the panoramic perspective to its opposite — several interesting sights which can be seen in the smaller fields of binoculars. This column is primarily devoted to naked-eye observations, which is a delightful activity whether or not you own a telescope or other optical instrument. But this month an inexpensive pair of binoculars could reveal to you three of the fainter solar system bodies involved in special events.

In the last issue, we discussed observing **Uranus** with the naked eye in fairly dark skies. This month, you'll need binoculars because on June 24 the 5.8 magnitude planet will go just 1'43" north of the 5.5 magnitude star 41 Librae. In September, when both are still observable, Uranus will return to pass only 7" from the star.

Uranus should be an easy sight in binoculars, but you may have a little trouble seeing, or even finding, the 7.7 magnitude **Neptune**, now at opposition. You will need detailed star charts and the position given in Through the Eyepiece. At month's end, Neptune is about ⅓° south of the location where the supernova known as "Kepler's Star" appeared in 1604.

One final world, roughly as bright as Neptune, has an unusual conjunction on June 29: **Ceres** is just 4' north of the 4.5 magnitude star Lambda (λ) Leonis (this star, also called Alterf, is just west of the point of the Sickle). Ceres, the largest asteroid, reaches perihelion on July 5 for the first time in 4.6 years, and is then 2.553 A.U. from the Sun.

Have you figured out what kind of event *will be occurring in the west late* this summer? Notice that late in June, Venus is roughly as far to the right of

Regulus as Jupiter and Saturn are to its left. Since Venus moves much faster along the zodiac than Jupiter and Saturn, we can forsee that it will overtake the pair fairly low in the western sky around late August — which is when Mercury will be returning to this area for its next evening apparition. Add the star Spica and the passing Moon, and it is clear that this late summer gathering will not soon be forgotten. During July and August we will also have a lunar eclipse and what could be the best Perseid meteor shower of the century!

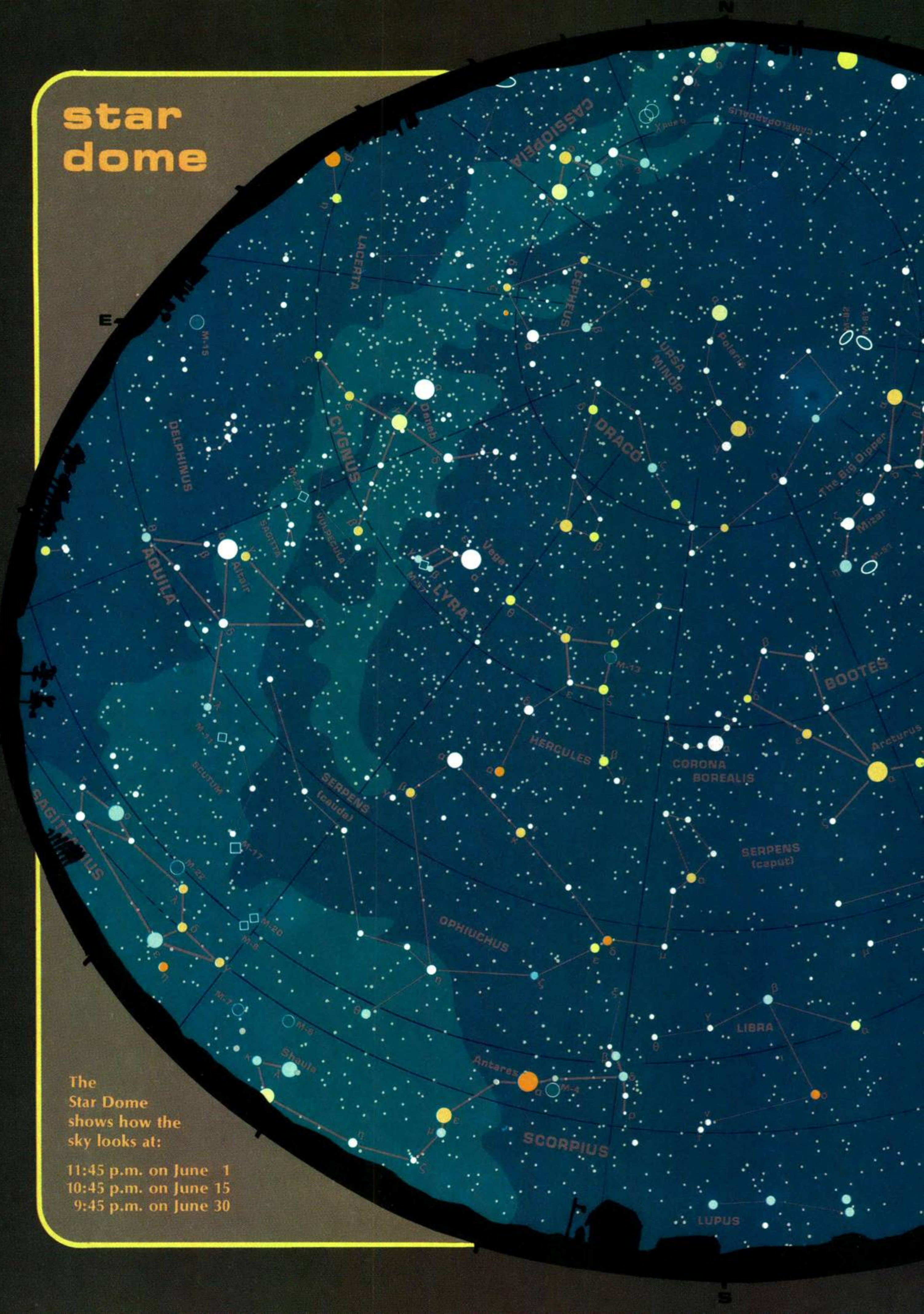
the starry sky

For those of us in the northern hemisphere, the twilights as well as the days are longest in June. Astronomical twilight officially ends when the Sun is 18° below the horizon, but at the high latitude of Britain that actually never happens on June "nights." Even observers at 40° N. must wait until after 10:30 p.m. (daylight saving time) for the end of astronomical twilight at this time of year. It is fortunate that we do not have to wait until the last afterglow of the Sun is gone to begin some good observing.

Above Venus and Mercury, and several bright stars disappearing into the solar glare, you will still notice the prominent twins **Pollux** and **Castor** in the west, and still higher the downslanting **Leo** (the lion). Also lowering, but still prominent in the northwest, is **Ursa Major** (the great bear) with its familiar **Big Dipper**. **Ursa Minor** (the lesser bear) now stands at its highest, above its brightest star, **Polaris** — the **North Star**. Notice the line of fairly faint stars that passes between the two Dippers, separating them. This is the tail of a famous beast to which we will return in a few

The stately ballet of Jupiter and Saturn in Virgo has been a familiar celestial sight this year. Here the two planets (Saturn at top, Jupiter at bottom right) form a triangle with the star Gamma Virginis. Jim Boardman took the photo February 19 with a 50 mm lens, 400 ASA slide film, and a three-second exposure.

star dome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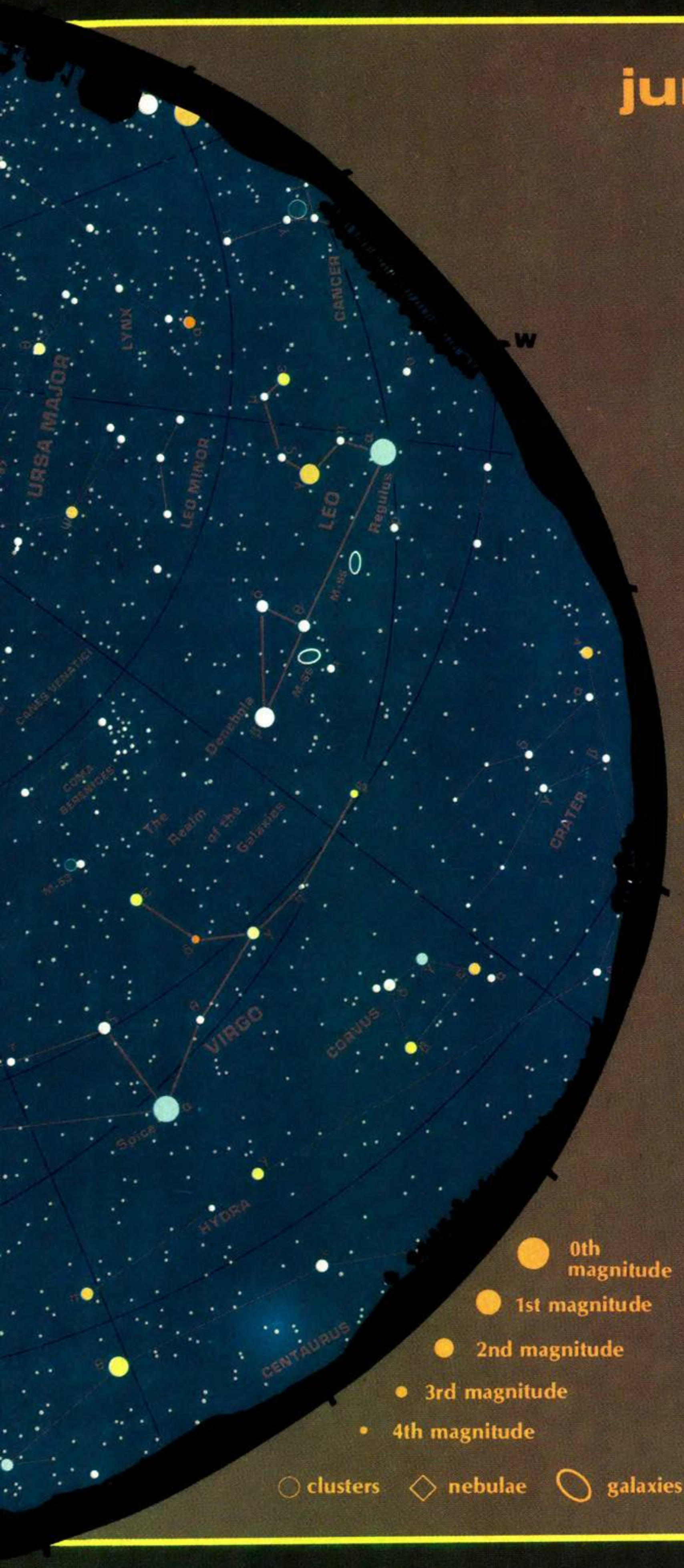
Arcturus
M-11
SCUTUM
SERPENS (cauda)
SAGITTARIUS
M-22
M-17
M-20
M-8
OPHIUCHUS
SERPENS (caput)
LIBRA
M-7
M-6
Shaula
Antares
M-4
SCORPIUS
LUPUS

The Star Dome shows how the sky looks at:

11:45 p.m. on June 1
10:45 p.m. on June 15
9:45 p.m. on June 30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The Realm of the Galaxies
M-53
CRATER
VIRGO
CORVUS
Spica
HYDRA
CENTAURUS
0th magnitude
1st magnitude
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

june sky almanac

1st The Moon is at perigee this morning: 222,751 miles. For the next week, the time known as the "dark of the Moon" means a good chance for you to get out into the country and learn some constellations under a truly dark sky.

2nd New Moon at 7:32 a.m. EDT.

3rd Look very low in the west just after sunset tonight and you'll see Venus (bright) with Mercury (pretty dim) to its upper right and a skinny crescent Moon (about 1½ days old) to the left of both.

8th Tonight and tomorrow night, Mercury will be fairly close to Venus in the western sky after sunset — look for dimmish Mercury to the lower left of much-brighter Venus.

9th First Quarter Moon at 7:33 a.m. EDT.

13th The Moon is at apogee tonight: 252,151 miles.

14th Neptune is at opposition to the Sun today.

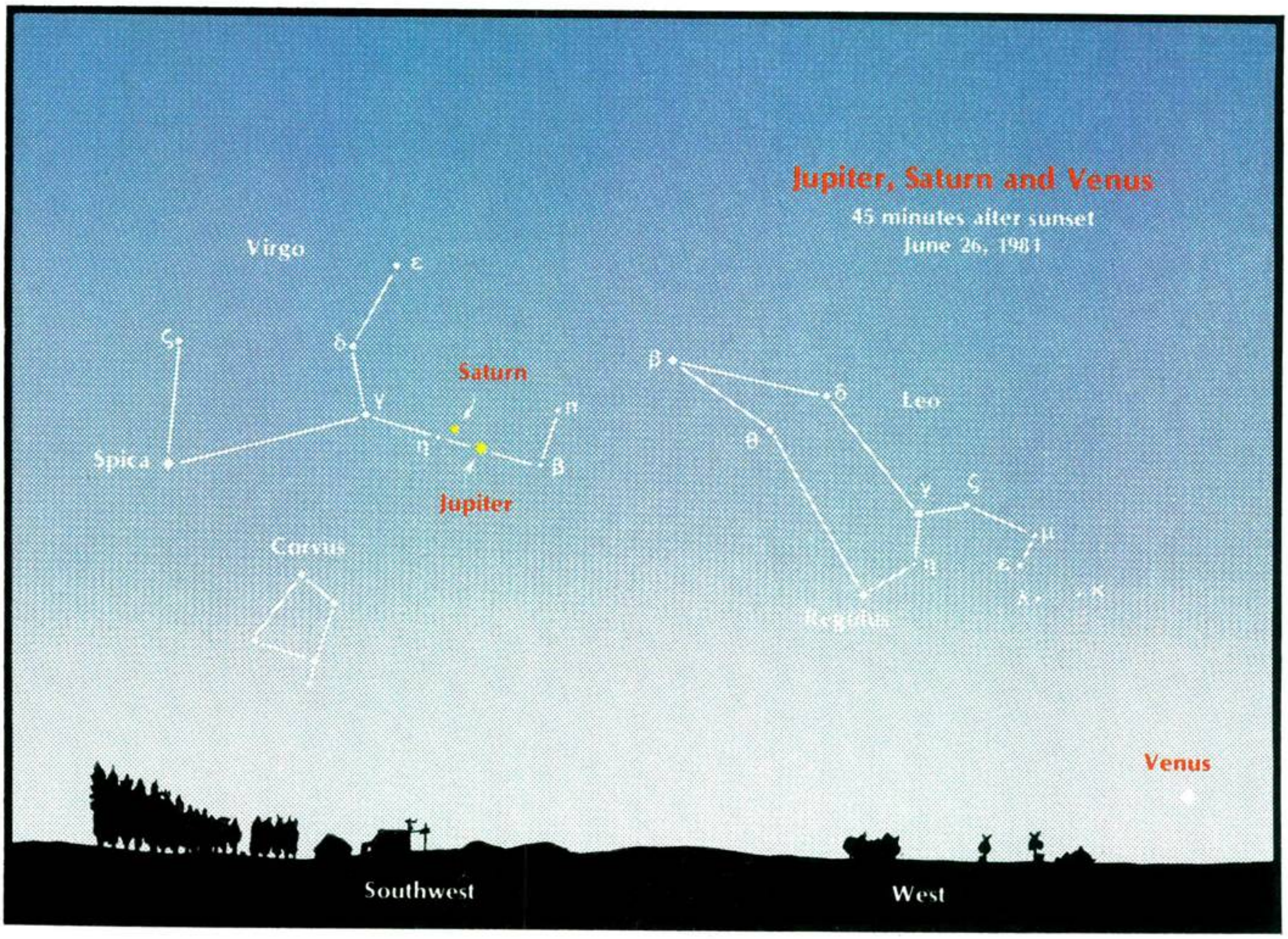
17th Full Moon is at 11:04 a.m. EDT — all but the brightest stars wiped out by the flood of moonlight. Mercury is at aphelion (farthest from Sun) and Venus at perihelion (closest to Sun).

21st The solstice happens at 7:46 a.m. EDT — northern hemisphere summer begins as the Sun halts its northward motion on the celestial sphere. Mercury is at inferior conjunction (between Earth and Sun).

25th Last Quarter Moon at 00:25 a.m. EDT.

29th The Moon is at perigee this afternoon: 225,154 miles. Asteroid Ceres passes very near Lambda (λ) Leonis this evening.

30th Just before sunrise this morning, look for a slender crescent Moon below Mars. (You may need binoculars!)



Jupiter, Saturn and Venus

45 minutes after sunset

June 26, 1981

moments.

As darkness finally grows deep, our attention is first drawn to the area of the southwest sky where Jupiter and Saturn gleam. They shine brightly by the faint head of **Virgo** (the virgin). Perhaps she is literally faintheaded, in a swoon, from lying in the Sun in the fields, for Virgo is always pictured reclining with an ear of wheat — her brightest star, **Spica** — held at her hip. She is also usually identified as the goddess Ceres, (the Greek Demeter) responsible for harvest and agriculture and all growing things. Study the Star Dome map to learn how to form this vast area of mostly dim stars into the roughly maidenly shape of Virgo.

Above Virgo's head and trailing Leo is the interesting but faint cluster of stars which makes up **Coma Berenices** (Berenice's hair). To the upper left of Virgo is a far more prominent constellation, **Bootes** (the herdsman). The stars of Bootes make a roughly human form, but the major object of attention here is one star: **Arcturus**, the brightest star in the northern celestial hemisphere. This point of light is the subject of our Skylore section this month.

The conspicuous half-circle of **Corona Borealis** (the northern crown) floats just to the left of high Bootes and next to his shoulder. It's brightest star is second magnitude **Gemma** (also called Alphecca), while none of the other stars are of more than average magnitude. But the other stars are all of similar brightness, and both the pattern and position of this constellation make it very conspicuous — few constellations are more renowned in the legends of so many lands.

Between Corona and the brilliant blue star in the northeast, we come to **Hercules**. The constellation itself is no brighter than Corona and is far more extended, but it is interesting for a number of reasons. Observers with telescopes esteem the name not primarily for its fine mythological associations, but for its globular star cluster **M-13**. M-13 is a glorious sight in any telescope, but in fairly dark skies you can glimpse it as a roughly 5.8 magnitude little patch of light in the western part of Hercules. This cluster is in fact conveniently located between the stars **Eta** (η) and **Zeta** (ζ) **Herculis** which together with **Pi** (π) and **Epsilon** (ϵ) form the Keystone of Hercules.

North of the Keystone is a smaller four-sided figure, roughly diamond-shaped. This is the head of circumpolar **Draco** (the dragon), featuring second magnitude Eltanin. The sinuous serpentine creature loops down from the head (that is, lower in the north) at this time of year, with its body coiling back up and finally twisting to the west, at last extending between the two Dippers. Its tail is the faint dividing line we encountered earlier in our survey.

The brilliant blue star below the Keystone is **Vega**, rivaling Arcturus and dominating the perfect little constellation **Lyra** (the lyre). Underneath Vega, lying low across the eastern sky like white breakers from the cosmic ocean, hangs the summer Milky Way. The brightest stars we see in it here are **Deneb** (to the left) and **Altair** (to the right), and these areas will be among our favorite celestial hunting grounds for the summer.

If we look well ahead of the Milky Way down into the southern sky, we see a dim constellation of present interest which we should not miss. The large faint diamond of stars is **Libra** (the scales), following Virgo on the zodiac. But following Libra is a rising constellation which is already spectacular. It is **Scorpius** (the scorpion), who creeps above the southeastern horizon, to expose his reddish heart-star **Antares**. This glittering monster will be one of our featured constellations next month.

skylore

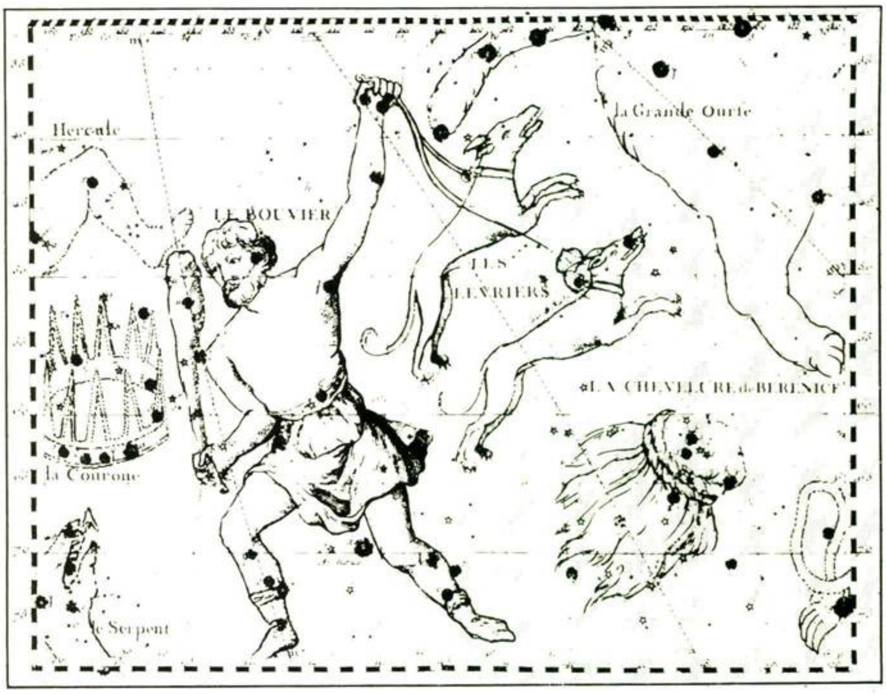
It could be argued that Arcturus is distinctive in more ways than any other bright star. Only a few — and less bright — first magnitude stars have such prominent colors. Its individuality benefits from its position — set apart in the midst of a large star-poor area and therefore all the more prominent. Modern astronomy has explained why this part of the sky is so sparsely starred and revealed facts which show that Arcturus is even more distinctive than previously thought. And there is even some twentieth-century skylore about this star.

The name Arcturus has been used since at least the time of Hesiod, the Greek poet. Hesiod flourished about 800 B.C., and one of the means of fixing the date is the writer's comment about the heliacal rising (first predawn appearance) of Arcturus.

Among many classical references to the star, some of the most interesting are those of Hippocrates, who thought Arcturus had considerable influence on human health. According to the father of medicine, a dry season after its rising (heliacal or opposition?) "agrees best with those who are naturally phlegmatic, with those who are of a humid temperament, and with women; but it is most inimical to the bilious."

Arcturus has been called Job's Star, because of the supposed reference to it in God's awesome speech to Job from out of the whirlwind. It is now believed, however, that the reference is to the Great Bear, not Arcturus: "Or canst thou guide the Bear with her train?"

R. H. Allen's classic book on star names and legends is a rich mine for Arcturus-lore, including the tales of relatively modern observers who have had special sights of the star. Allen records Smyth's claim that Arcturus was the first star ever observed in the daytime with a telescope — in 1635 by Morin. Allen also mentions that Schmidt had seen Arcturus with the naked eye 25 minutes before sunset. I know a present-day amateur astronomer who has viewed Arcturus easily without optical aid just before sunset. This person may have particularly good vision for such observations, but it seems fairly certain that a diligent observer with average eyesight can spot Sirius with the Sun slightly above the horizon. This month is an excellent time to test how soon after sunset — or even how long before — you can glimpse Arcturus with your naked eye.



Other fascinating examples of observing lore about Arcturus include its alleged loss of color for a few years after March 21, 1852 (according to Schmidt, Argelander, and Kaiser of Leyden) and the marvelous conjunctions of the star with several great comets. The famous Donati's Comet, discovered near Lambda (λ) Leonis on June 2, 1858, passed in front of Arcturus with the nucleus just 20′ from the star on October 5. The curved tail of Donati's Comet was then about 33° long and five days later reached a length of 60° (about to 51 million miles). But an even greater comet passed its tail over Arcturus 240 years earlier. The mighty comet of 1618 had a tail 104° long, a reddish hue, and was visible even in the daytime. John Bainbridge wrote of the conjunction: "The 27th of November, in the morning, the comet's hair was spread over the faire starre Arcturus, betwixt the thighs of Arctophylax, or Bootes."

As the only stars brighter than about third magnitude in a giant slice of sky, Arcturus and Spica have often been linked together in lore. To the Arabs, they were the two Simaks (probably "Lofty Ones") — Arcturus the "armed," and Spica the "defenseless." In China, Arcturus and Spica marked the horn-tips of the Dragon, a vast constellation which stretched from our Virgo to Sagittarius. Spring arrived (and was greeted with joy) when the Full Moon was seen between Arcturus and Spica, when it "rode the Dragon's Horns."

Eskimos, not surprisingly, used Arcturus as a timepiece when they went to net seals in the dark season of December and January. They called the star Sibwudli. The Shawnee Indians have a rich and delightful tale of Arcturus as White Hawk, a young warrior who married the youngest and fairest of the dancing heavenly sisters who compose Corona Borealis (a constellation whose circle is now incomplete with the loss of the fairest one). But in India, one of the names of Arcturus was Nishtya, the Outcast, probably because it was so far from the zodiac of which it formed one of the "lunar mansions."

But Nishtya would also be a good name for Arcturus because of its solitary position explained (and made all the more fascinating) by modern astronomy.

We now know that the north galactic pole is not very far from Arcturus, so when we look in this area, we are gazing up out of the thickly star-populated plane of our Galaxy toward the intergalactic void. Arcturus, scientists tell us, orbits our Galaxy in a very highly inclined fashion compared to the orbits of the Sun and most other stars we see. We are fortunate to be living in the era when Arcturus is diving down through the plane and is now almost at its nearest to the solar system. A half million years from now, Arcturus will be too distant to see with the naked eye, as it was to the earliest humans. This gypsy star is racing past us to journey for eons in the southern wilderness below the Galaxy's main wheel.

And so new facts are substance for new lore. Another fine example of twentieth century skylore involves Arcturus: this is the only star ever to have opened a world's fair. The famous 1933 fair in Chicago was opened by light from Arcturus that was directed onto photocells. It was believed that the light had left the star 40 years earlier — the date of the previous Chicago fair — but we now believe that Arcturus is 37 light-years away.

ASTRONOMY
IN FOCUS

OMB

Sir / I am concerned over the problem NASA has in receiving federal funds. I'm sure practically everyone in the U.S. has seen the continual slashing of financial support by government officials in Washington, DC and now I'm afraid a new barrage of cuts are on the way.

On January 8, 1981, ABC News reported that during his hearing for confirmation as the head of the Office of Management and Budget, David Stockman implied that he could even cut NASA funding for 1981. He said this to Senator John Glenn no less!

NASA has been very successful since its inception and it continues to be so — witness the recent success of Pioneer Venus and the Voyager missions to Jupiter and beyond. Where would we be now if Queen Isabella hadn't given Christopher Columbus the financial support needed in his quest for The New World?

Thomas J. Fields
Tory, NC

The 300" Dobsonian?

Sir / Re the 300-inch Texas Monster: one look at the pix and accompanying text was all it took to convince me that Texas not only wants to build the world's largest telescope, but also the world's largest Dobsonian! Consider the overall lightness of the design, the large alt-azimuth mount, the thin mirror. I do hope they make it from something other than porthole glass.

"Sourdough" Jim Jackson
Lakewood, CA

"Texan-sized" Telescopes

Sir / This is a note of appreciation. Thank you for your AstroNews item on the McDonald Observatory 300-inch telescope (ASTRONOMY, February 1981). Texas *should* have the biggest!

Jimmy Didear
Streetman, TX

Mr. Didear / Alas for Texas! See AstroNews in the March issue — Lick Observatory (in California) is actively planning a 400-incher.

A Sirius Observation

Sir / At 4:30 p.m. on March 17 (while the Sun was still well above the horizon), I was able to see and follow the star Sirius with my naked eye for about five minutes.

I was watching a gull as it flew by when I noticed a pinpoint of light in the southeastern sky. I later confirmed what I'd seen by looking at Sirius in a darker sky and by checking with a star atlas.

I wonder if other observers have experienced this.

Giuseppe Pepi
Hollywood, CA

A 3-inch Newtonian "Catalog"

Sir / After reading the In Focus section in the March 1981 issue of ASTRONOMY "3-inch Spectacular," I would like to tell of my own experiences with a 3-inch Newtonian. The telescope itself isn't much, but it did much more than I thought it would.

This is a short list of some of the objects I have observed: the Moon, the Andromeda Galaxy (M-31), the Orion Nebula (M-42), the great Hercules Globular (M-13), the Pleiades (M-45), the Beehive Cluster (M-44), M-35, M-41, M-8, M-20, M-11, M-17, M-22, M-4, also the planets Venus, Mercury, Jupiter, Saturn, Mars, and Uranus, and many of the brighter stars and double stars in the sky.

Some of these objects were faint and hard to see, but I was greatly satisfied by the performance.

The way I line up my 3-inch is pretty much the same way Rick Ramsey does, shoving the tripod and moving the tube up and down until the object appears in the finder.

The reason I wrote this letter is because Rick Ramsey's experience is somewhat related to mine. I am 15 years old and have owned my 3-inch for a year and a half.

Joseph Gagnon
Williamstown, VT

Info Sources

Sir / I have two questions on sources. First, where can I get the daily positions of Titan and any other satellites of Saturn that I might expect to see in my 13-inch Dobsonian? And second, where can I find a list of stars in the solar neighborhood (out to, say, 100 light-years)?

Peter Koch
Milwaukee, WI

Mr. Koch / The times of eastern elongations as well as apparent distance and position angle for saturnian satellites are tabulated in the **Astronomical Almanac**. *This yearly publication (formerly known as the* **American Ephemeris and Nautical Almanac**) *is available in most public and large university libraries, as well as being sold ($13 for the 1981 volume) by the U.S. Government Printing Office, Washington, DC 20402.*

The standard source list of stars near the Sun is Wilhelm Gliese's **Catalogue of Nearby Stars**, *published as #22 in the Veroeffentlichungen ("Contributions") series of the Astronomisches Recheninstitut, Moenchhofstrasse 12-14, 69*

Heidelberg, West Germany. The **Catalogue** *can usually be found in large university or astronomy department libraries. It may still be in print (though published in 1969); we suggest you write to the Rechen-institut if you are interested in buying a copy.*

Contributing

Sir/February 15th, 1981 marked the first anniversary of the Solar System Exploration Fund (SSEF). A cashier's check for $500, 100% of donations received, was mailed to NASA.

There are several pro-space groups but only the SSEF and the Viking Fund are directly contributing to NASA. The Viking Fund is for continued R&D on Viking's Mars Data. The SSEF's purpose is to supplement NASA's shrinking budget and to support it throughout the probable planetary sciences cutbacks of the Reagan Administration.

NASA does allow for contributions from private groups. Donations must go into NASA's General Services Fund and are allocated to the program with the greatest need. Any donations for a specific program, however, will go the USA Treasury. SSEF's contribution will go to NASA's General Fund. NASA was quite pleased and grateful for SSEF's efforts.

Donations to the Solar System Exploration Fund may be sent to Chester Twarog, Chairman, 1943 Paris Street, Aurora, CO 80010. Include SASE if you want receipt acknowledged. If you include a short letter supporting NASA and telling why, I will send it to President Reagan. I will send out a quarterly newsletter to each donor describing the current status of the SSEF. The success of NASA's planetary sciences, spacecract, and eventual industrialization and colonization depends on your active support of a dynamic and progressive space program.

Chester Twarog
Aurora, CO

Editor's Note: The Viking Fund contributed $60,000 to NASA's Project Viking to continue receiving data from the Viking Lander. Contributions should be sent to: The Viking Fund, 357 Saratoga Ave., Santa Clara, CA 95050.

Observational Letdown

Sir / After having many people over for a night's session at the eyepiece, I've noticed a disturbing number walk away in disappointment. "Where are the giant swirls of gas and stars?" they often ask.

Telescopic views to match the preconceived notions in the heads of first-time "astronomers" generally can't be found in the amateur eyepiece. Sure, a view of the Moon, Saturn and maybe a few clusters will bring an "ooh" or an "ahh," but from then on it's all downhill.

Observational astronomy is much like playing a musical instrument — the more you practice, the better you get. Training the eye to pick up texture, shades in contrast, and even color, requires time and patience at the eyepiece.

So it's a good idea to explain to friends and neighbors what they're looking at and how far away and how big it is. Comparative values may help: "It's eleven times bigger than Earth" helps them to see Jupiter. Also show them objects well within your telescope's visual range. Save the sights at the visual limit for you and other astronomers.

Try not to get angry when all they can see is the focal length and brand name of the eyepiece — a briefing in a lit room would be of great value here. And lessons on how to look through an eyepiece and stay clear of the declination axle can save you lots of time in re-acquiring the target.

Visual astronomy can be enjoyed by all, but only, it seems, if it's presented in proper perspective. I hope seasoned amateur astronomers will continue to share their skills, knowledge and patience with those who are new to astronomy. And I wish them clear skies and good seeing.

Peter C. Herman
Huntington, IN

Observatory Information

Sir / I own an 8-inch Schmidt-Cassegrain telescope that I want to install in a permanent location. I've been looking for information for the past months, but I can't find much on this "down to earth" aspect of astronomy. Where can I find some of the vital details in the area of domes and roll-off roofs? It would help me a lot.

Gordon Ripley
Solon, ME

Mr. Ripley/ As you may know, AstroMedia also publishes **Telescope Making**, *a magazine about telescopes — and of course it features articles about observatories, too. Recently we've put together a reprint booklet of nine observatory projects described in TM, from a modest shelter from streetlights to some elegant domes. This may provide you some useful background. (See our advertisement on page 63 for more information.)*

behind
the scenes

observing season again

As we finish the June issue of ASTRONOMY, I'm looking ahead to the return of warm weather and pleasant nights for observing. Last week we had several nights warm enough to keep me comfortable outside with just a light jacket. One night, I carried out my 4-inch and 6-inch reflectors and took a look at the bright clusters along the Milky Way in Gemini and Auriga. Jupiter and Saturn looked so good that the next night I set up my 12-inch Newtonian in the side yard for a better look at them.

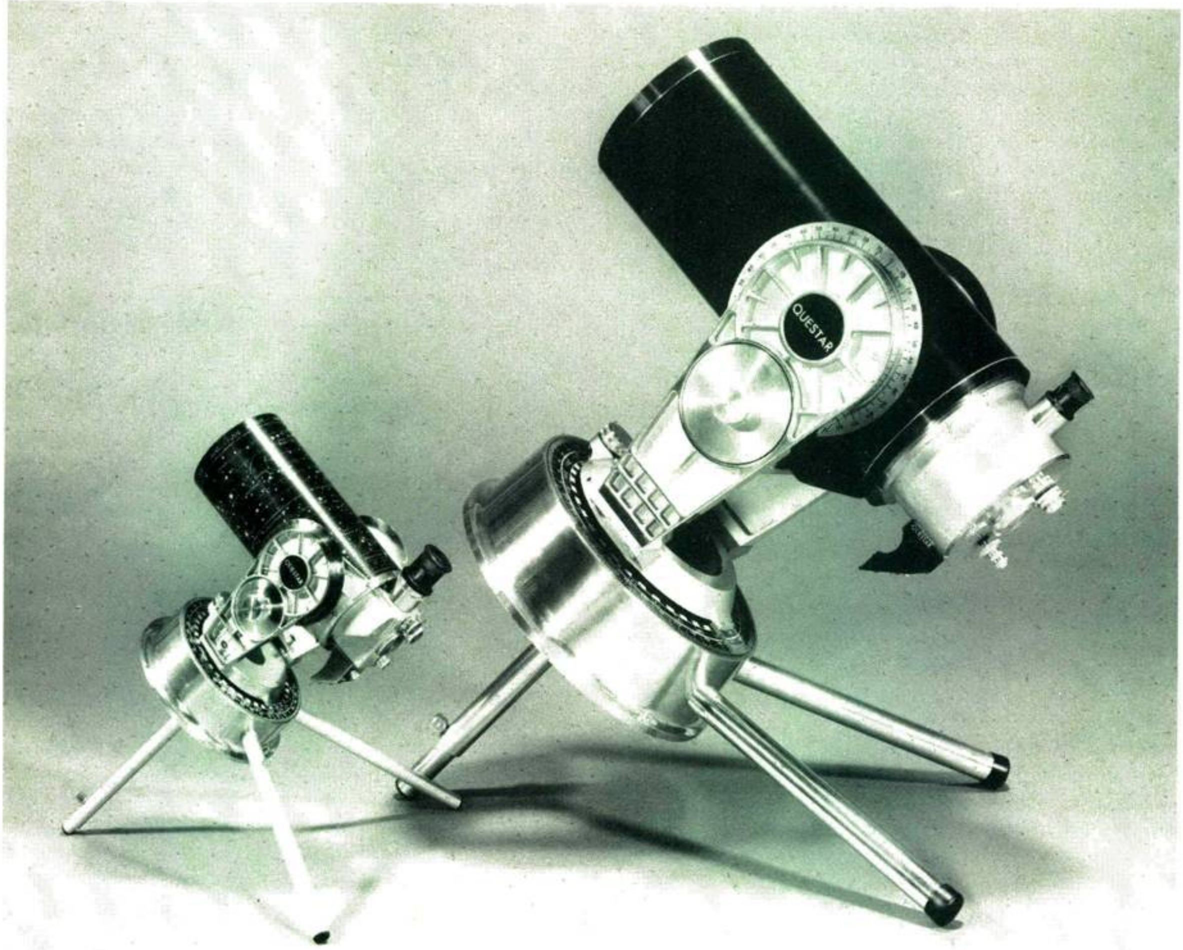
As an unexpected bonus, Jupiter's moon Io was in transit. At first, I only saw Io's dark shadow, but as the satellite moved toward Jupiter's limb, its disk stood out clearly. For about 40 minutes, I watched the slow-motion spectacle: Io moving to the limb, forming a little bump on the side of Jupiter, and finally sliding away from the planet. It was one of those rare nights when seeing is superb. The detail visible in the belts was breathtaking — pastel festoons and swirls — and I could see the disks of the satellites with no problem. At 250x, they looked like tiny marbles.

Turning to Saturn, I saw Titan and four of the little moons, Cassini's Division, and the rings almost blending with the planet where they passed in front. But the recent Voyager images kept coming into my mind's eye — tiny Mimas with its big crater, Rhea and Dione's scarred faces, the hundreds of ring divisions — and I marveled. How fine a thing it is that we humans sent a big funny-looking machine out there to explore those worlds! Just to know what's out there. Just to know.

Sincerely,

Richard Berry

Richard Berry



THE INCOMPARABLE QUESTAR SEVEN

Here the Questar Seven is shown as the overshadowing companion of its world-famous predecessor—twice as large and with double the performance: a portable observatory with the same superb mechanical and optical qualities as the Questar 3½, putting every refinement of the observatory telescope at your fingertips.

Would you believe that a fully-mounted telescope with 7 inches of aperture could be so completely portable? It can be set up wherever you want it in just the length of time it takes to lift barrel and mounting from two matching cases and join them together with a knurled screw. It can be used on a tabletop, either in its altazimuth form or in its polar equatorial position, achieved by screwing three legs into place.

The Seven also has the famous Questar system of built-in conveniences: low-power finder, high-power changes without changing eyepieces, star diagonal prism, synchronous electric drive, setting circles, worm-driven sidereal clock, and continuous 360° smooth slow motions. All are included in the price of the telescope, and included too are the Questar totally safe solar filter and basic camera coupling set.

The Questar Seven is photovisual, of course, with four times the light grasp of the Questar 3½, and has the same easy way of adding a 35-mm. camera to the control box without disturbing the use of the eyepiece.

The remarkable Questar drive impresses everyone who uses it. Hubert Entrop, who takes beautiful deep-sky photographs (a number of which we have published here and in our recent issue of QUESTAR OBSERVATIONS), frequently comments on the quality of the drive. He has written us: "The motor drive on the Seven works very smoothly and quite precisely, even though the guiding is being done at twice the focal length of the 3½."

Another time, when sending us some pictures, he said, "The Seven base drive is so smooth that the shutter in the off-axis guider was not used even once for all four of these exposures." And again, "With the Seven there is never any problem in guiding; it no doubt has the best motor drive of any scope outside of observatory equipment."

These comments come from an observer who is using his equipment in all sorts of difficult terrain, on mountains, in the desert, and often under the most adverse weather conditions. In this regard he once wrote us that pictures he was sending to us were taken in winds gusting to 40 m.p.h. He concluded, "So these results are a tribute not only to the optics but also to the Questar design and drive mechanism."

You might well ask what an amateur astronomer like you can do with a telescope so fine that it is in constant demand as a component of costly tracking instruments requiring the utmost in mechanical accuracy and superb resolution. The plain fact is, you can *see* more! You can see *more* detail on the moon and planets, photograph the "rice grains" on the sun's surface, capture the fascination of deep-sky objects on film, and use it terrestrially, for the sharp definition of any distant object. There are no frustrations with Questar's diffraction-limited optics nor with its mechanical components. They are as fine as the hand of man can make them.

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observing planetary nebulae

by
F. Michael Witkoski

The 18th century was a time of great ferment in astronomy. Newtonian physics, still fresh from its maker's hand, was unfolding a new universe. The solar system became a gigantic clockwork: the Moon, the planets, and comets all swept through the skies with gratifying predictability. As if to cap it all, in 1781 William Herschel discovered the first new planet since antiquity — Uranus — and doubled the known size of the solar system.

Beyond the Sun's family lay other discoveries: Herschel and his contemporaries found and cataloged hundreds of double stars, variables, and nebulae. Among these last (a catch-all for anything not recognizably stellar) were certain objects whose small, greenish disks bore a startling resemblance to the newly-discovered Uranus.

For this reason, astronomers named them *planetary nebulae*, a name we are now stuck with after two centuries of misuse. Today, we know they have nothing at all to do with planets: a planetary nebula is the glowing cloud of gas thrown off late in life by a star not massive enough to blow up in a supernova explosion.

Such a star sheds its outer layers almost gently; its envelope of gas expands slowly as it drifts away, and often forms a near-perfect sphere around the parent star. This "shell" looks like a ring because we see more glowing material at its edges than in the center. But other nebulae have different appearances: some look flat and disk-like, some have structure on their "faces," and some describe an hourglass shape.

Planetaries are transient; we see few that are more than 50,000 years old. By the time it is about 100,000 years old, a nebula has expanded and diffused to the vanishing point.

They belong to our Milky Way galaxy and presumably exist throughout it, though clouds of dust and gas limit us to seeing only those nearby. In addition, sheer distance would reduce any that exist outside our immediate neighborhood to star-like dots, because most planetaries have diameters of only a light-year or two.

To the telescope owner, planetary nebulae are an endless source of delight. You'll find them all over the sky and in any season. From the largest (which has an apparent diameter half that of the Moon) to the smallest (barely more than a star), there's a fascinating array. Even with a small telescope, you can find a few dozen. Many more, ranging down to the point where they become indistinguishable from stars, will appear in larger instruments.

photo by Leo Henzl

M-57, the Ring Nebula

Summer Skies

The best time of year to look at planetary nebulae is the northern hemisphere summer. In the sky then you'll find two of the finest examples: the Ring Nebula (M-57) in Lyra and the Dumbbell Nebula (M-27) in Vulpecula.

The famed Ring is the prototype for the entire group, and a "favorite of favorites" for both casual and dedicated observers. The nebula has a total magnitude of 8.9, and its oval donut shape is apparent even in a small instrument. You'll notice that the ends of the oval are noticeably dimmer than the long sides; this is common with "ring-type" planetaries.

The Ring Nebula has a central star, but since its magnitude is only 14.0, you'll need at least an 8-incher to make it out.

Unlike the roundish Ring, the Dumbbell resembles two hazy masses in delicate and balanced contact. The larger the instrument you view with, the more distinctly you'll see its hourglass shape. The nebula has a magnitude of 7.6 and although its central star is brighter (magnitude 12.0) than the Ring's, it is harder to see because it lies embedded in the glow of the nebula.

The Ring and the Dumbbell differ markedly in apparent size: the more diminutive Ring measures 83 x 59 seconds of arc versus the Dumbbell's 480 x 240. The Ring Nebula, because of its compact configuration, will stand lots of magnification — even up to a few hundred times if atmospheric "seeing" is excellent.

Both are very easy to find. For the Ring, look about midway and just a bit south of a straight line between Beta (β) and Gamma (γ) Lyrae. For the Dumbbell, scan about 3½° north of Gamma (γ) Sagittae. (You'll also find both objects plotted on just about any sky atlas.)

The Ring and Dumbbell tend to overshadow many other planetaries in the rich summer sky — some quite easily visible in small or medium telescopes. One of the most impressive is NGC-6826, the Blinking Nebula, in Cygnus. Lying 5½° north of third magnitude Delta (δ) Cygni, it shares a wide field of view with the fine double star 16 Cygni, lying ¾° to the west.

In contrast to both the Ring and the Dumbbell Nebulae, NGC-6826 has a conspicuous central star. When you

where to find them

NGC	other	constellation	r.a. (1950.0)	dec.	size	magnitude	
						nebula	star
40		Cepheus	00h 10m	+72° 15′	60″ x 38″	10.7	11.6
246		Cetus	00h 45m	-12° 09′	240″ x 210″	8.0	10.5
650/1	M-76	Perseus	01h 39m	+51° 19′	157″ x 87″	11.0	16.6
1514		Taurus	04h 06m	+30° 38′	120″ x 90″	9.0	9.4
1535		Eridanus	04h 12m	-12° 52′	20″ x 17″	9.6	10.0
1714		Dorado	04h 52m	-67° 01′	8″ x 8″	10.0	
2022		Orion	05h 39m	+09° 03′	28″ x 27″	12.3	13.0
IC-2149		Auriga	05h 53m	+46° 07′	15″ x 10″	9.9	10.2
2371/2		Gemini	07h 22m	+29° 35′	54″ x 35″	13.0	12.5
2392	Eskimo	Gemini	07h 26m	+21° 01′	47″ x 43″	8.6	9.1
2438		Puppis	07h 40m	-14° 36′	68″ x 68″	9.7	16.8
2440		Puppis	07h 40m	-18° 05′	54″ x 20″	9.1	
2867		Carina	09h 20m	-58° 06′	12″ x 12″	9.7	
3132	Eight-Burst	Antlia/Vela	10h 05m	-40° 11′	84″ x 53″	8.2	
3242	Jupiter	Hydra	10h 22m	-18° 23′	40″ x 35″	9.0	11.7
IC-2621		Carina	10h 58m	-64° 58′	2″ x 2″	10.5	
3587	M-97, Owl	Ursa Major	11h 12m	+55° 18′	203″ x 199″	11.4	14.3
3918		Centaurus	11h 48m	-56° 54′	10″ x 10″	8.0	
4361		Corvus	12h 22m	-18° 29′	81″ x 81″	12.8	12.8
IC-3568		Camelopardalis	12h 32m	+82° 51′	18″ x 18″	9.0	10.8
IC-4406		Lupus	14h 19m	-43° 55′	100″ x 37″	10.6	
5882		Lupus	15h 13m	-45° 27′	7″ x 7″	10.5	
IC-4593		Hercules	16h 10m	+12° 12′	15″ x 11″	10.2	10.2
6210		Hercules	16h 43m	+23° 53′	20″ x 13″	9.7	11.7
6302	Bug	Scorpius	17h 10m	-37° 03′	120″ x 60″	11.4	10.0
6309		Ophiuchus	17h 11m	-12° 51′	19″ x 10″	9.7	13.0
6369		Ophiuchus	17h 26m	-23° 44′	28″ x 28″	9.9	16.6
6543	Cat's Eye	Draco	17h 59m	+66° 38′	22″ x 22″	8.8	9.6
6572		Ophiuchus	18h 10m	+06° 50′	16″ x 13″	9.6	12.0
6629		Sagittarius	18h 23m	-23° 14′	16″ x 14″	10.6	13.6
6720	M-57, Ring	Lyra	18h 52m	+32° 58′	83″ x 59″	8.9	14.0
6741		Aquila	19h 00m	-00° 31′	9″ x 7″	10.2	16.7
6781		Aquila	19h 16m	+06° 26′	106″ x 106″	10.3	15.4
6818		Sagittarius	19h 41m	-14° 17′	22″ x 15″	9.9	12.0
6826	Blinking	Cygnus	19h 43m	+50° 24′	27″ x 24″	8.8	9.9
6853	M27, Dumbbell	Vulpecula	19h 57m	+22° 35′	480″ x 240″	7.6	12.0
6891		Delphinus	20h 13m	+12° 35′	15″ x 7″	9.0	10.0
6905		Delphinus	20h 20m	+19° 57′	44″ x 37″	10.5	14.2
7008		Cygnus	20h 59m	+54° 21′	86″ x 69″	10.0	12.0
7009	Saturn	Aquarius	21h 01m	-11° 34′	44″ x 26″	8.4	12.0
7027		Cygnus	21h 05m	+42° 02′	18″ x 11″	10.4	17.1
7048		Cygnus	21h 13m	+46° 04′	60″ x 50″	11.0	18.3
7293	Helix	Aquarius	22h 27m	-21° 06′	900″ x 720″	6.5	13.3
7662		Andromeda	23h 24m	+42° 14′	32″ x 28″	9.4	15.6

shift your gaze rapidly between looking directly at it and looking slightly away, the star and the nebula alternately blink on and off! Even telescopes as small as 4″ aperture will show this effect, which is common with all planetaries having bright central stars.

The richness of the Milky Way in this area makes NGC-6826 tricky to pinpoint, so proceed carefully.

Three other Cygnus planetaries are NGC-7027, which appears almost stellar and very blue-green at magnitude 10.4; the relatively sprawling NGC-7048 at magnitude 11.0 (use low powers with this one); and the wispy NGC-7008 at magnitude 10.0.

Ophiuchus houses two small planetaries, NGC-6572 (which looks distinctly greenish) and ring-shaped NGC-6369 — magnitude 9.6 and 9.9 respectively. Both of these can be seen in small telescopes.

Other summer planetary nebulae include 9.7 magnitude NGC-6210 in Hercules (bluish fuzz), NGC-6629 and NGC-6818 in Sagittarius (10.6 and 9.9 magnitude), and NGC-6543 in Draco (hazy oval shape) — one of the finest in the sky at magnitude 8.8

NGC-6543 has historical significance, since it was the first planetary nebula to be observed with a spectroscope (in 1864, by Sir William Huggins). That observation settled a controversy over whether planetary nebulae were composed of numerous unresolvable stars or were merely clouds of diffuse gas. The line emission Huggins saw proved their gaseous nature. As it is practically a circumpolar object, you can see NGC-6543 most nights of the year.

Fall Skies

Autumn displays fewer planetaries than summer, but there's no lack of interesting objects.

One of comet-hunter Charles Messier's "objects-that-look-like-a-comet-but-aren't," M-76 in Perseus lies well-placed in the early fall sky. Unlike most planetaries, it has two distinct components and, under low magnification, resembles a miniature Dumbbell Nebula. It has picked up the nickname the Barbell Nebula perhaps because of this emulation. This elongated fuzzy object will allow substantial magnification, but only on nights of very good seeing.

M-76 ranks among the dimmest (11.0 magnitude) of the Messier objects, and it's puzzling why Messier recorded this object and overlooked literally hundreds of others much brighter. Look for M-76 just under 1° north-northwest of Phi (ϕ) Persei.

Far brighter (magnitude 9.4) than M-76 is NGC-7662 in Andromeda — a planetary usually overlooked in favor of its spectacular spiral galaxy neighbor, M-31. Round and slightly ring-shaped, NGC-7662 has a distinctly blue-green hue and is one of the sky's best planetaries, despite its small size of 32 x 28 seconds of arc. About 300 times brighter than M-76 per unit of surface area, NGC-7662 stands up well under magnifications that would make M-76 all but fade into the background.

Shifting our attention to the sprawling constellation Aquarius, we encounter two fine, yet dramatically different, planetaries: the Saturn Nebula (NGC-7009) and the Helix Nebula (NGC-729).

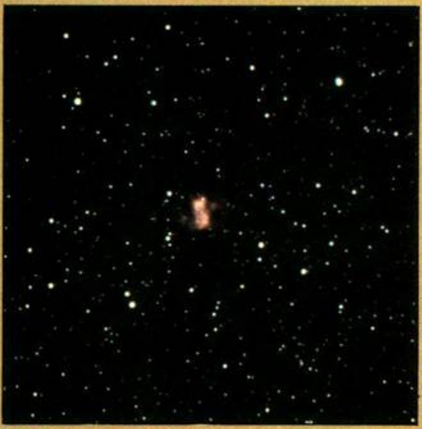


photo by Bill Iburg

M-76, the Barbell Nebula

The Saturn Nebula lies about 1½° west of Nu (ν) Aquarii. It has a magnitude of 8.4 and extends 44 x 26 seconds of arc — about average.

Conspicuous in photos are two "ears" that give a shape reminiscent of its namesake, but they are difficult or impossible to see in instruments under 6" aperture. Instead, you'll see what looks like an out-of-focus blue-green oval star. The nebula's central star has a magnitude of 12.0 and is quite difficult to see though the brightness of the nebula itself.

About 22° southeast of the Saturn Nebula lies the Helix Nebula, the largest planetary in the sky. It measures a giant 900 x 720 seconds of arc, approximately half the apparent diameter of the Moon!

With an integrated magnitude of 6.5, the Helix Nebula ranks first of all planetaries in total brightness. Yet paradoxically, it's one of the more difficult and elusive — even eagle-eyed William Herschel missed it. The problem comes down to "low surface brightness": all its magnitude gets spread out over a lot of sky.

Accordingly, you'll find a wide-field, low-power eyepiece essential — lacking such an accessory, keep the magnification as low as you can. (You may even find that binoculars work best.)

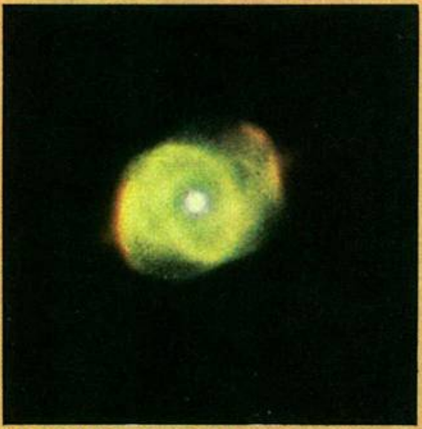
Your first impression will be of a large diffuse ball of fuzz. If the seeing is good, and the skies dark, you may notice the center is slightly darker and the beginnings of a wreath-like structure are evident. Photographs, of course, reveal the complex and twisted wisps which earned it the name "helix" — Greek for spiral object.

Given the relatively poor conditions most observers must contend with, you really should be satisfied just to *locate* it. Its appearance is so sensitive to atmospheric conditions that any haze or light pollution will obliterate it completely. Also, don't expect to see any color. Your eye's color sensitivity depends critically on brightness, and any given area of this nebula just hasn't enough to activate the color-sensing parts of your retina.

The nebula's central star cannot be seen easily through a small telescope, but since it has a magnitude of 13.3, you could pick it up with a 6" or larger.

At declination +72° lies NGC-40, a 10.7 magnitude planetary in Cepheus. About half the size of the Ring Nebula and possessing a very conspicuous central star, NGC-40 shows a small, 60 x 38 arc-second oval disk.

Many telescope owners never see this object because it lies far from any guide stars. But it is close to the pole and well-placed for viewing at some time, virtually any night of the year. The only planetary lying closer to the pole and observable in modest telescopes is magnitude 9.0 IC-3568 in Camelopardalis — a small round disk that needs good magnification to reveal much.


Lick Observatory photo

NGC-6543, the Cat's Eye Nebula

Winter Skies

The cold skies of winter are renowned for their bright stars and rich open clusters — but you'll also find some good planetaries scattered throughout.

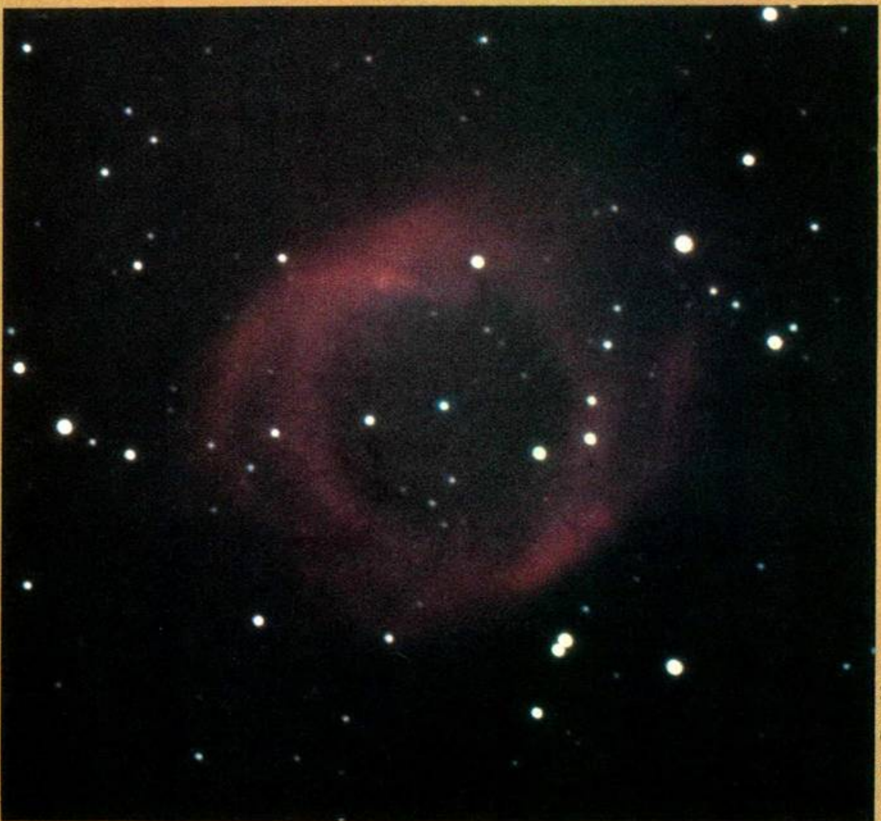
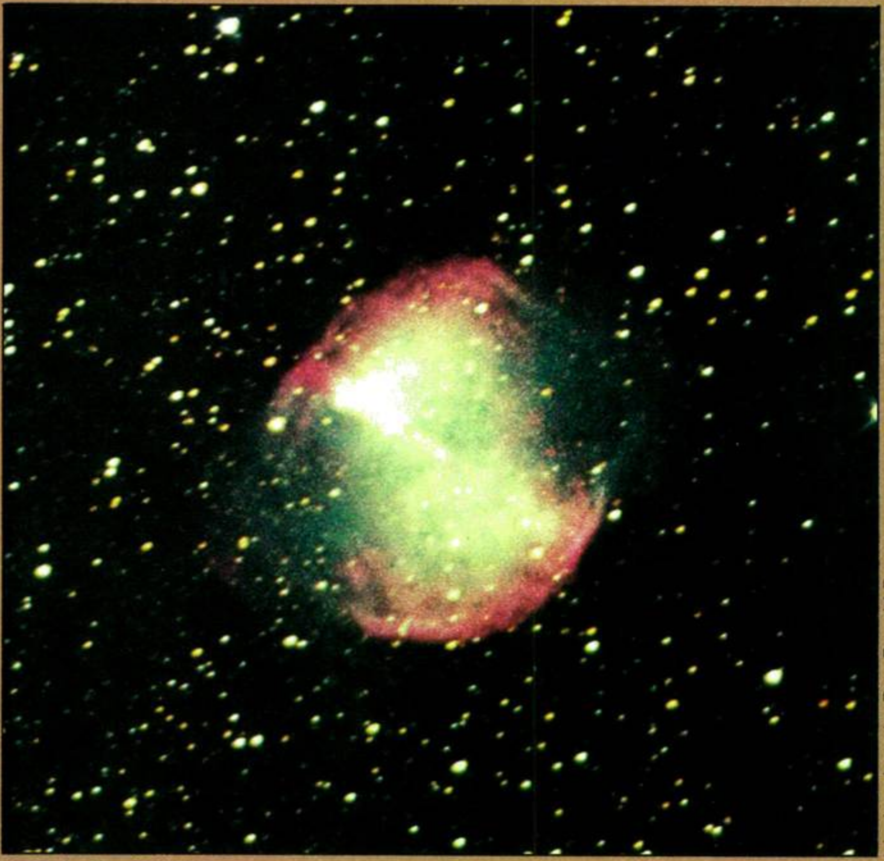


photo by Ben Mayer

NGC-7293, the Helix Nebula

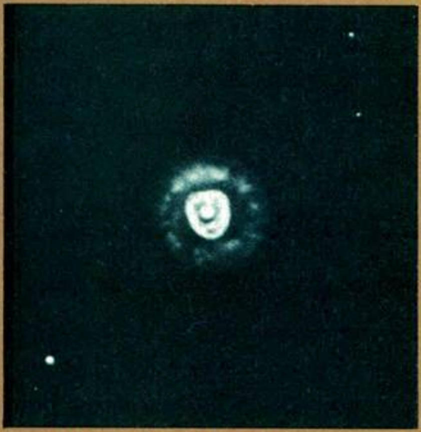


M-27, the Dumbbell Nebula

tricolor photo by Rev. Ronald Royer

Foremost is 8.6 magnitude NGC-2392, the Eskimo Nebula, in Gemini. One look at a good photo gives the name away — but you won't see the surface mottlings suggestive of a human face wrapped in a furry hood unless you use a very large telescope. Instead, expect to see a greenish central star with a ring around it.

NGC-2438 in Puppis is very easy to locate: it lies superimposed on the northern edge of the fine open cluster M-46. Appearances to the contrary, the nebula has no physical connection with the cluster; it's simply a "foreground" object. In larger instruments, the nebula looks like a round fuzzy spot, with perhaps a hint of a dark center.



NGC-2392, the Eskimo Nebula

Lick Observatory photo

Scan 3½° south from NGC-2438 and you'll see NGC-2440. Measuring 54 x 20 seconds of arc, it is somewhat smaller than NGC-2438 (68 x 68 seconds). Much more than most of its kind, NGC-2440 — diminutive, ghostly and blue-green — epitomizes the classic planetary.

These two, at magnitudes 9.7 (NGC-2438) and 9.1 (NGC-2440), offer a fine challenge to anyone using a small instrument. Use the "guide cluster" M-46 for help in finding them.

Other winter planetaries are NGC-1535 in Eridanus and IC-1249 in Auriga. Both are bright, and will appear nearly stellar.

Spring Skies

In springtime, most deep-sky observers take a long wallow in a sea of galaxies. But drag yourself away from them and take a look in Ursa Major, 2½° southeast of Beta (β) Ursae Majoris. There you'll find M-97, the Owl Nebula — the fourth and last of the Messier objects in our survey.

The Owl Nebula's name comes from the two dark areas on its disk which, when seen in very large telescopes, resemble eyes peering at you out of the night. The view in a 12-incher with the very best sky conditions will start to hint at the owl-like face, but smaller apertures reveal only a featureless and nearly circular disk.

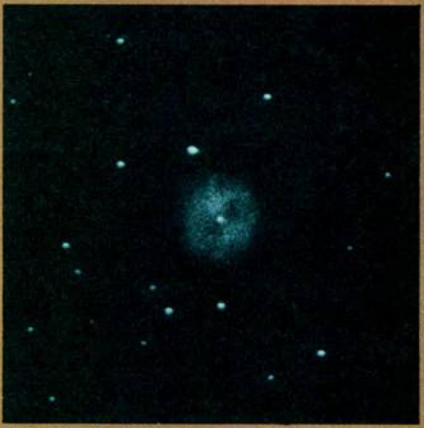
Though listed at magnitude 11.4 and theoretically one of the more difficult of the Messier objects, the grey-greenish disk of the Owl really isn't hard to see even in 3" or 4" instruments. Added bonus: within a degree of M-97 lies the galaxy M-108, a ready steppingstone from Beta (β) Ursae Majoris.

The southern planetary NGC-3132 in Antlia — nicknamed the Eight-Burst Nebula from its appearance in long-exposure photos —is one of the finest in the sky. About as large as the Ring Nebula and 1.4 magnitudes brighter (8.2 vs. 9.6), the Eight-Burst is rarely observed from northern latitudes because of its low declination, -40°.

You'll find it a hazy oval, 84 x 53 seconds of arc, shining bluish-white. Were it more visible from these latitudes, it would undoubtedly outshine many of the accolades of the Ring and the Dumbbell.

At 22° north of the Eight-Burst lies another fine planetary, NGC-3242, nicknamed "the ghost of Jupiter." It lies about 2° south of the naked-eye star Mu (μ) Hydrae. NGC-3242 looks like a round greenish-blue smudge. It's dimmer than the Eight-Burst (magnitude 9.0), but more compact, so its surface brightness is about equal.

Of course, far more planetaries than these exist — as a glance at any detailed atlas will show. From our location 30,000 light-years from the center of the Milky Way we can see scarcely a thousand out of an estimated 50,000 scattered throughout the Galaxy and hiding behind light-years of dust.

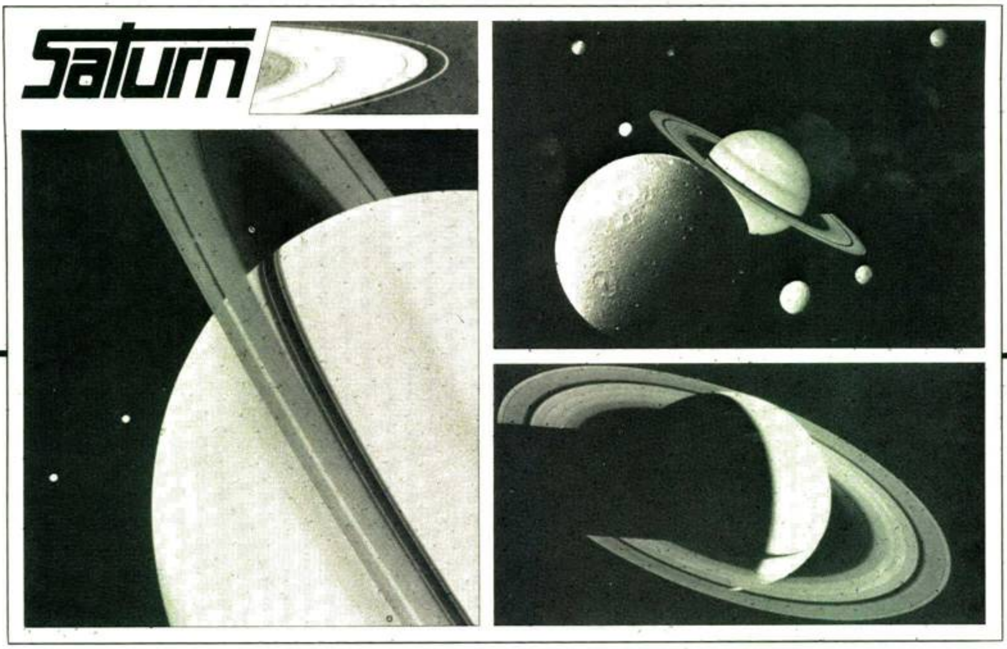


M-97, the Owl Nebula

photo by Bill Iburg

But it's senseless to fret over wonders we'll never see. The fun of planetary nebulae lies in finding those we can and observing how each is unique in some way — thus getting on friendly terms with another feature of the heavens.

Michael Witkoski has been a deep-sky observer for several years. He generally uses an 8" telescope and is working on a project to observe all the NGC items it will detect. His last ASTRONOMY article, on observing diffuse nebulae, appeared in July 1980.



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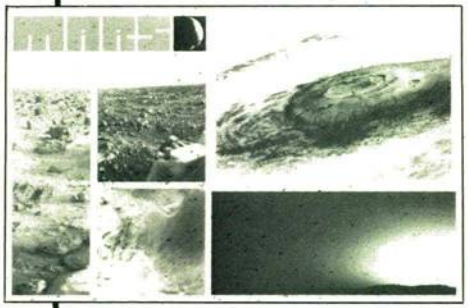
The Planets



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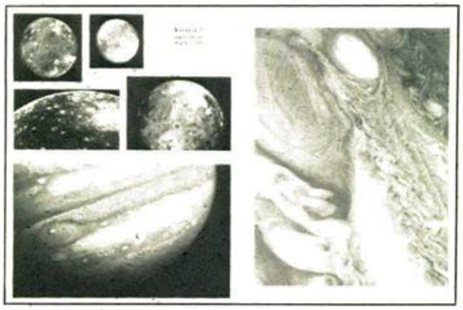

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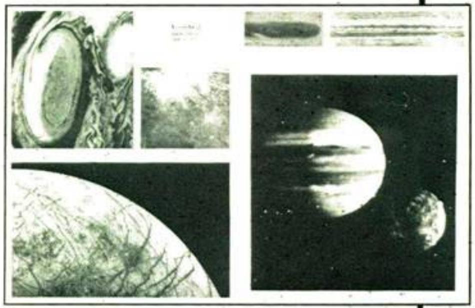

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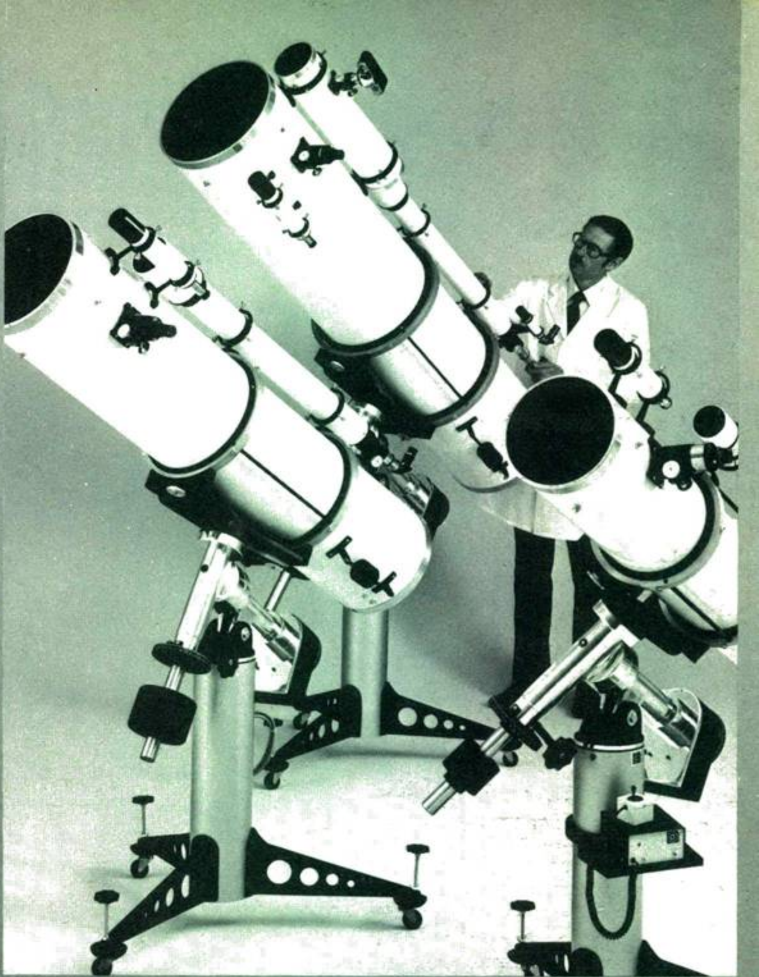

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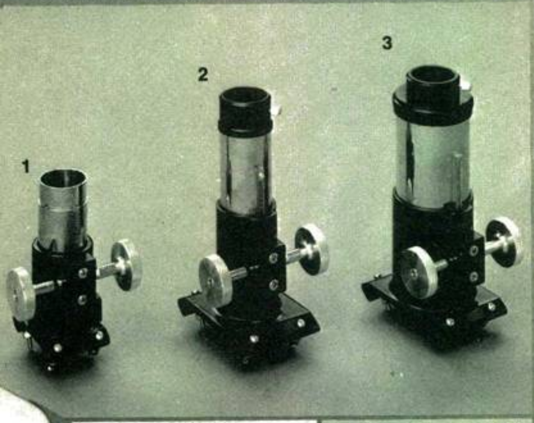

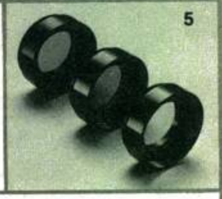

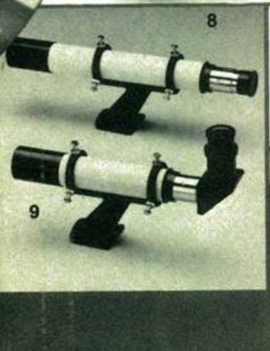

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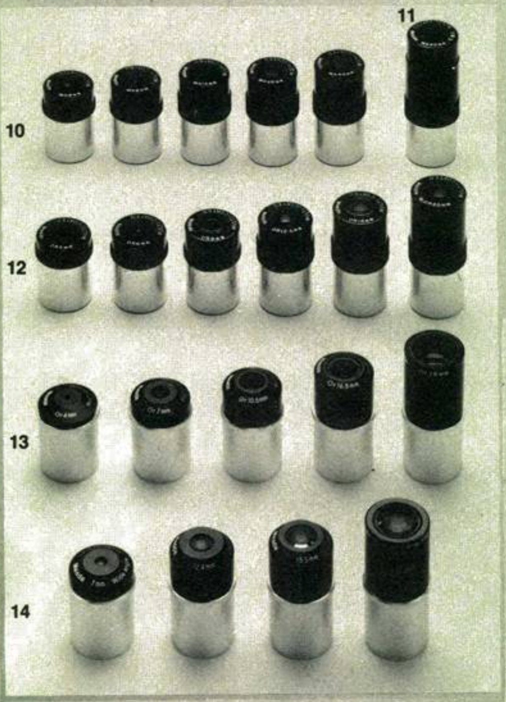

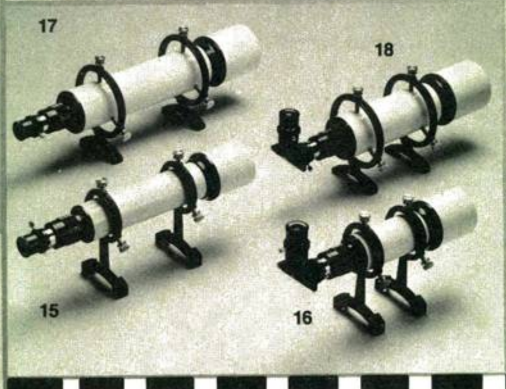

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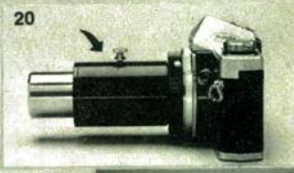

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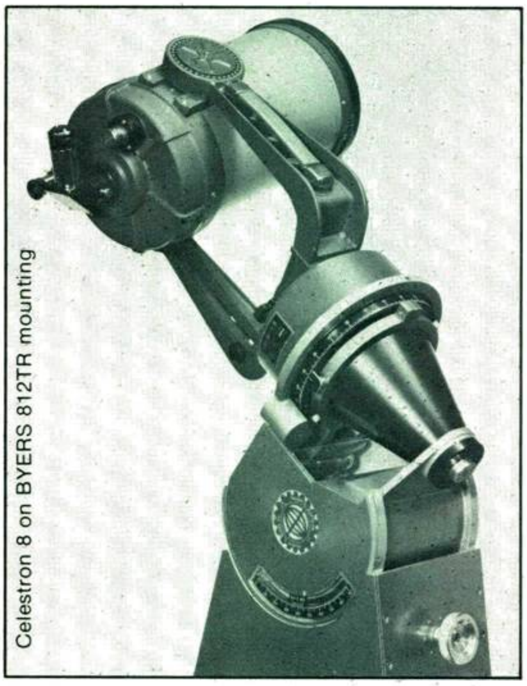
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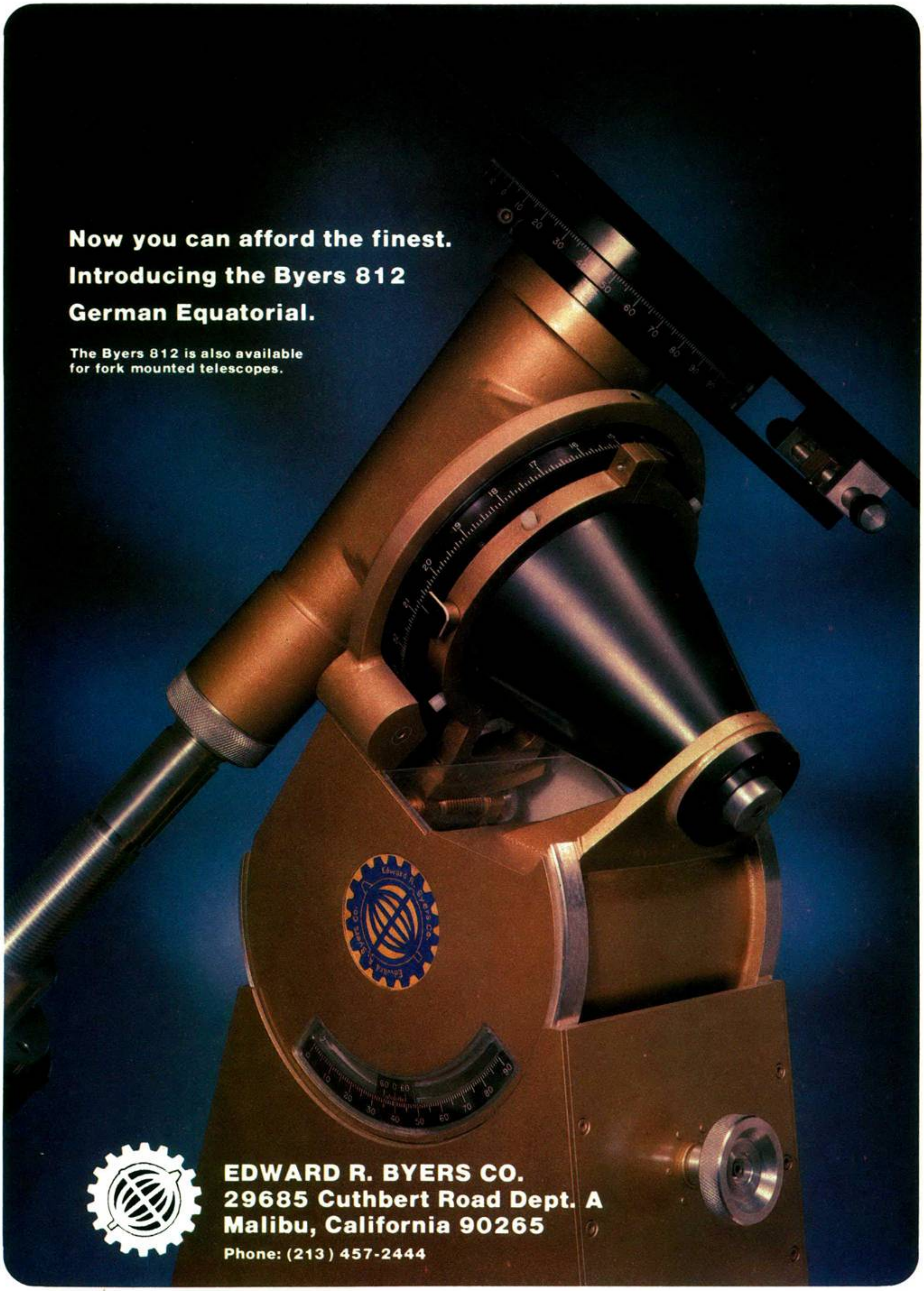

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equipment
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is bigger always better?

by Carl Fischer

Many astrophotographers lament the small size of their telescopes when they see colorful photos of Messier objects and faraway galaxies that were exposed for hours through the eyepieces of leviathan telescopes.

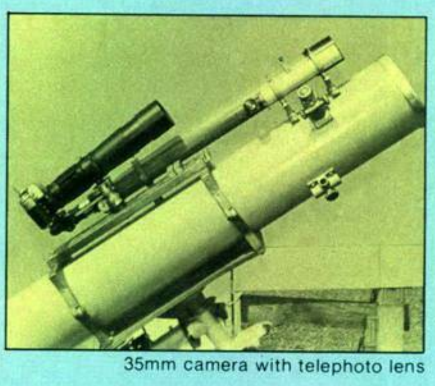
But is bigness the only way to go? For a long time, I thought it was. I spent a lot of time gazing at telescope catalogs, contemplating whether to get another Newtonian or a Cassegrain — in the 20-inch category, naturally! But all that has changed now that I've realized I haven't even come close to exhausting the possibilities of my 6-inch Newtonian.

Although I am a professional photographer, I took very few pictures through my telescope the first year I had it. Instead, I did a lot of visual sky exploring. When I had made pictures, they were only of the brighter objects in the sky — those requiring ten seconds or less exposure.

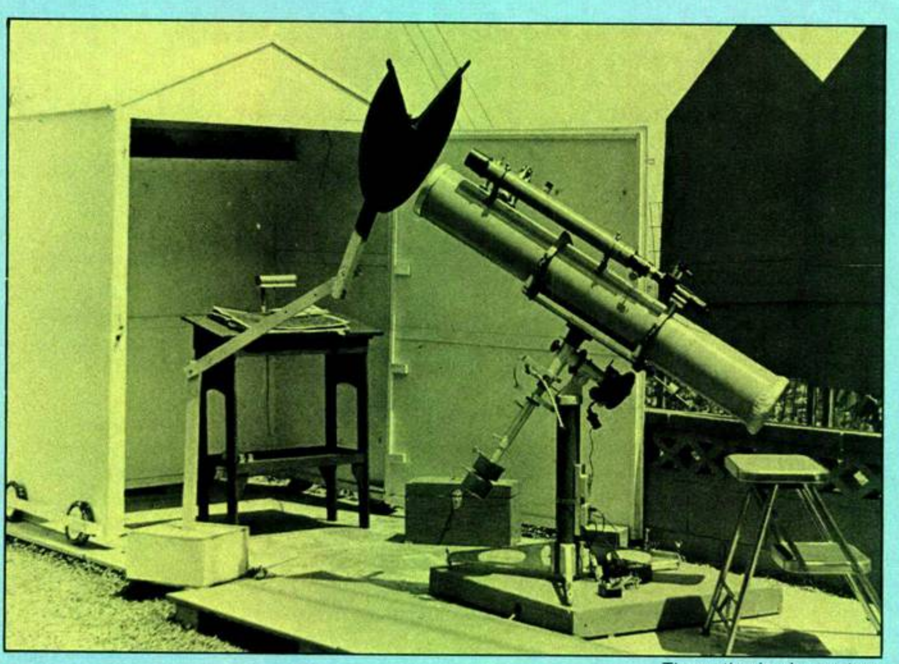
Naturally, I decided I needed super-fast film. Although I shoot all my pictures on Tri-X film, I develop them in Diafine developer to which I add an extra 25% distilled water. I also double the developing time, and bubble nitrogen gas through my developing tank. With this method, I can raise the speed of the film above 3000 ASA.

When I first decided to explore all the possibilities of my scope, I added an 800 mm focal length refractor guidescope with a lighted eyepiece and a drive corrector so I could accurately track a planet, star cluster, or galaxy.

Adding all this, plus the heavy battery case, played havoc with the balance of my telescope. Then I built brackets to hold several (not just one) twin-lens reflex cameras to the telescope. Now I was set up to make lots of photographs! But first I had to mount bars on each side of the telescope to hold weights for counterbalancing the added equipment. I made my own weights of 1, 1½ and 2 pounds by pouring molten lead into small tin cans. After they cooled, I removed them from the cans and smoothed them on a lathe.



35mm camera with telephoto lens



The author's observatory

I'm sure you've suspected by now that mounting several piggyback cameras in addition to all the other equipment on the instrument demands a lot of experimenting with the weights in order to get the unit into perfect balance. You're right! Sometimes I spend as much as three hours balancing the telescope before I'm ready to take a picture, and there are many nights when I make only one exposure. But the negatives I get from that one exposure are very satisfying: they show thousands and thousands of stars over a comparatively wide segment of sky. And using several cameras to record the same sky area helped me become more familiar with some interesting star groups.

Next, I built a camera holder to anchor the camera over the eyepiece. First I locate the sky object with the viewing lens, and then I zero in the focus. A set screw locks the focusing mount in place, and I move the taking lens into position. Then I'm ready to shoot.

I decided to add a 35 mm camera — equipped with a 400 mm lens — to ride shotgun on the telescope. If I want a larger area of sky, I piggyback another 35 mm camera with a 300, 200, or even a 135 mm lens — all depending on how large an area I want for the particular shot.

M-22

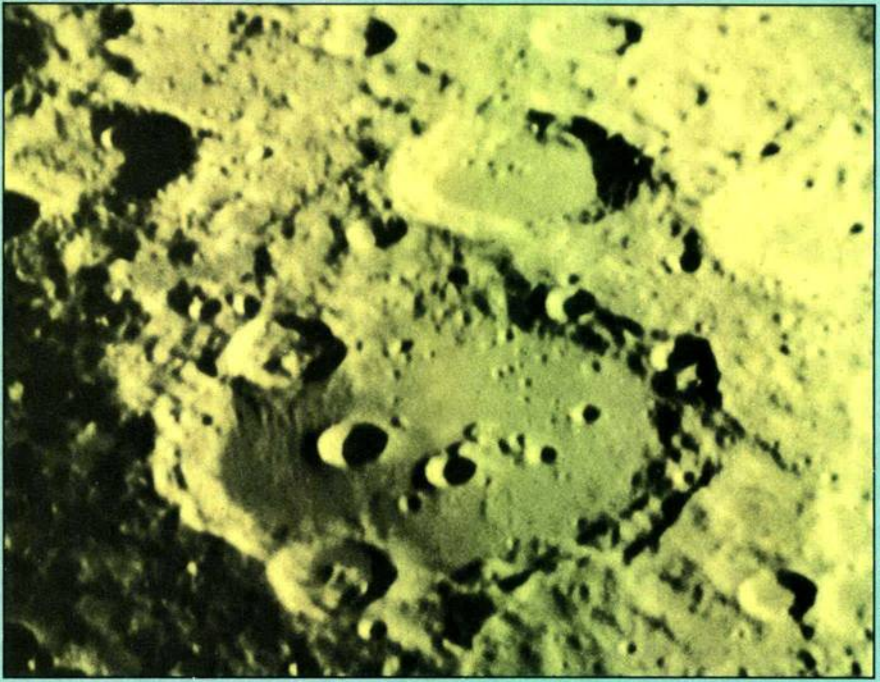
by Chris Bowland

With the added equipment, it was not feasible to move the telescope indoors each morning. So I built a roll-away telescope house that allowed me to leave it set up properly at all times.

With my telescope now fully equipped, I systematically photographed all the Messier objects I could locate. After developing the films, I make contact prints as a record of what's on the negatives. I then make an enlargement of the primary object in each negative with whatever enlarger lens gives the best rendition. Any other interesting objects appearing on the negative — star clusters, visible doubles, or galaxies — are also enlarged to 8 x 10. All the enlargements are made on Kodak's Polycontrast RC paper and put through a stabilization printer. I file all the pictures made from the two or three negatives of the same object in separate envelopes numbered according to a system, so I'm able to check back on the prints whenever I want. One particularly galaxy-filled segment of the Virgo sky gave me 32 separate 8 x 10 pictures!

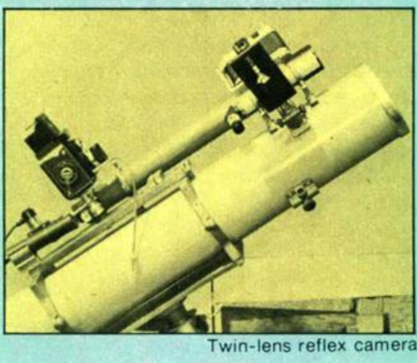
Saturn

by Geoff Briggs


Clavius

by Ron Price

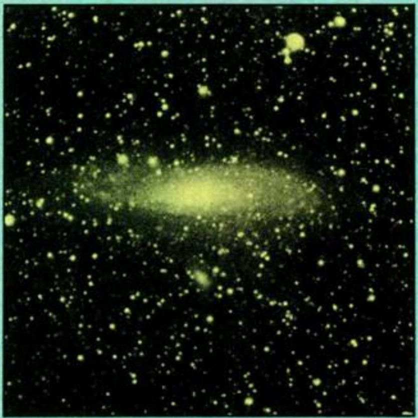
For close-up lunar pictures which require a very short exposure, I use an outside shutter. Camera shutters cause too much vibration in the telescope and prevent a good picture. I had to practice plenty to turn the black plywood disk with its one open segment at the right speed to approximate fractional parts of a second.


Twin-lens reflex camera

Another thing I found: Critical focusing is important for making good astrophotographs. Most reflex cameras have a built-in magnification lens, which can be suspended above the ground glass, but you can augment this magnification with a good hand lens. However, extremely critical focusing is more difficult with an SLR 35 mm camera. There are now critical focusers available for nearly all makes of 35 mm cameras. These either screw into or slip over the viewing window and they give an 8x magnification. I use these focusing helps on all my 35 mm cameras.

Because of light pollution, my exposures rarely run over 15 minutes. Occasionally, as with some dim Messier objects, I tried a 30-minute exposure, but the glare of the city lights interfered too much to permit good pictures. Sky glare does not pose much of a problem as long as I keep exposures to 15 minutes or less.

Quite an impressive list of things to do with a "lowly" 6-inch scope, isn't it? So, before you give in to the temptation and plunk down hundreds or even thousands of dollars for a "big" scope, why not think about what you can still do with what you have? You may find it will be years before you've exhausted all the possibilities of your present instrument. I've had so much fun with my "small" telescope that the itch for a bigger one is now gone. In my book, bigger isn't necessarily better!


M-31

by Tom Koed

Carl Fischer is a professional photographer in Los Angeles, California. He took the equipment photos accompanying this article.

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getting the correct exposure

photography in astronomy

Film prices are running high, dark "photographic" skies often lie a long drive away, and nights with good or better seeing are infrequent. With all this facing you, plain common sense calls for making every exposure count.

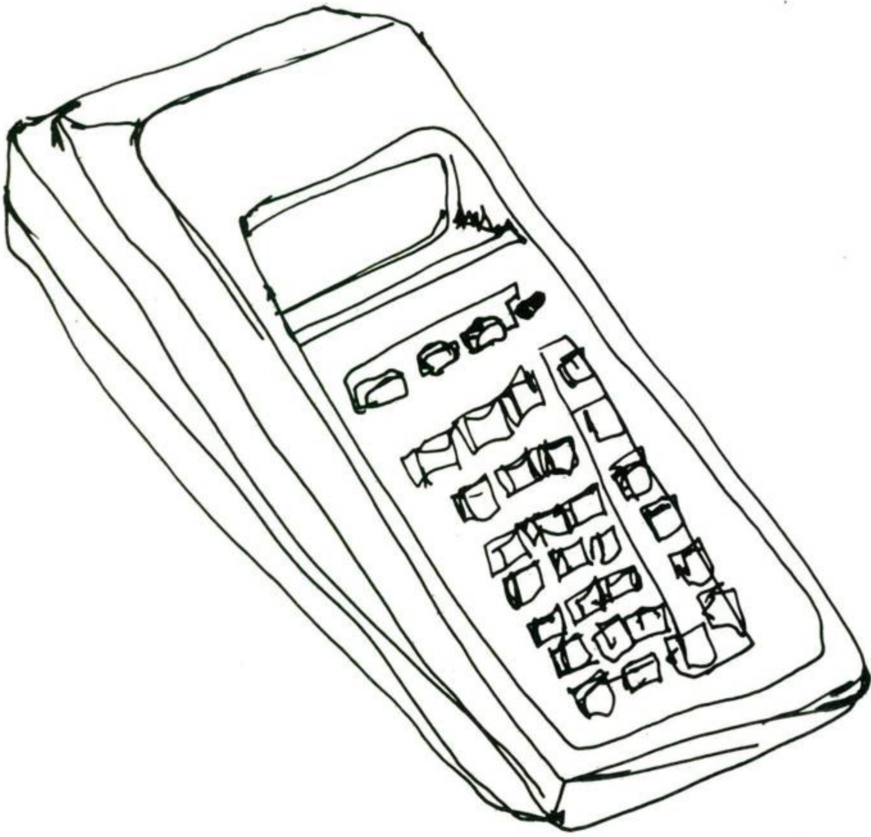
But how?

The answer begins with knowing some facts about your subject and your photographic system. Let's review the basic elements: film speed, subject brightness, and f/ratio.

Film speed lies as completely in your control as subject brightness lies beyond it: the first you can choose; the second you learn to allow for — and at the end of this article we'll show you an easy way to do just that.

It's the third item — f/ratio — that drives most beginners to distraction. They're convinced they can never figure out the f/ratio of a system that could have as many as four separate image-forming optical elements. It all seems complicated, difficult, and uncertain.

But the worry is needless: a few simple computations that involve nothing more than basic arithmetic will tell you all you need to know.



Rusty with pencil-and-paper? Even the dumbest "four-banger" calculator will more than suffice.

Let's start with the simplest system, your ordinary camera lens. How do you find its f/ratio? Read it off the engraved dial: f/2 (some show 1:2). But what does f/2 mean? It means the lens aperture — defined by the metal iris — has an opening half as wide as the focal length is long. Set at f/2, your 50 mm lens has an opening 50/2, or 25 mm (about 1 inch) wide.

Now let's say you remove the camera lens and, using an appropriate adapter, attach the camera body to the telescope's eyepiece holder.

In effect, this makes your telescope a telephoto lens that has the same focal length and f/ratio as the scope itself. Thus a 6-inch f/8 Newtonian telescope can become a 48" (1220 mm) f/8 telephoto lens. It's that simple.

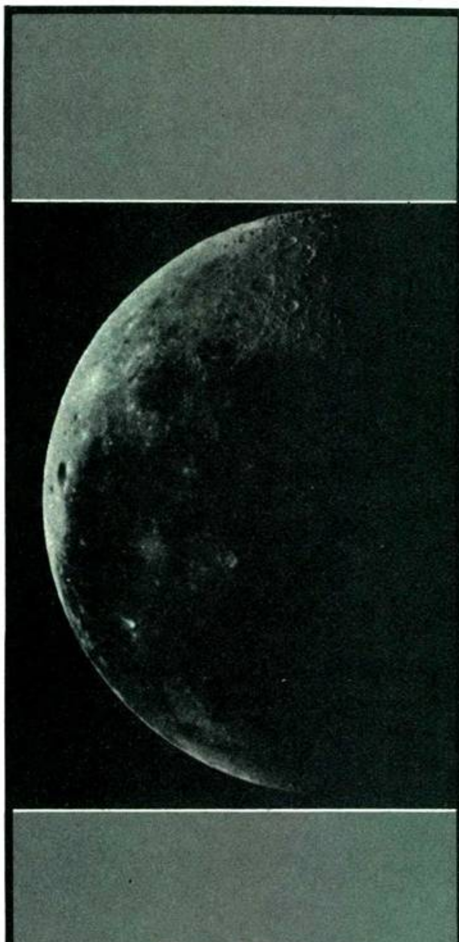
A second widely used system is the "afocal" method. This couples a telescope and eyepiece together with your camera and its lens. In an afocal rig, you aim the camera and lens into the telescope's eyepiece and snap the picture. Accordingly, you need to know how to calculate the "working" f/ratio, given a specific telescope/eyepiece and camera/lens combination.

Start by determining the magnification of the eyepiece and camera lens combination: divide the camera lens focal length by the eyepiece focal length:

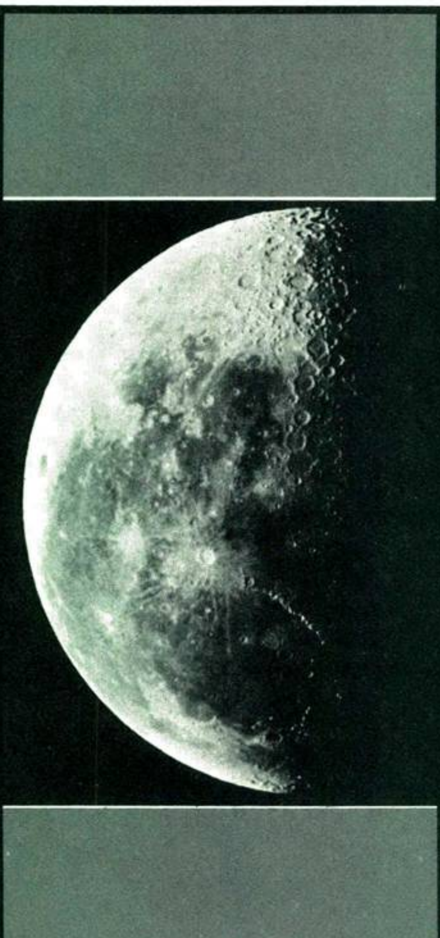
$$M = \frac{\text{camera lens f.l.}}{\text{eyepiece f.l.}}$$

A 28 mm eyepiece and a camera with a 50 mm lens make the magnification 50/28, or about 1.8.

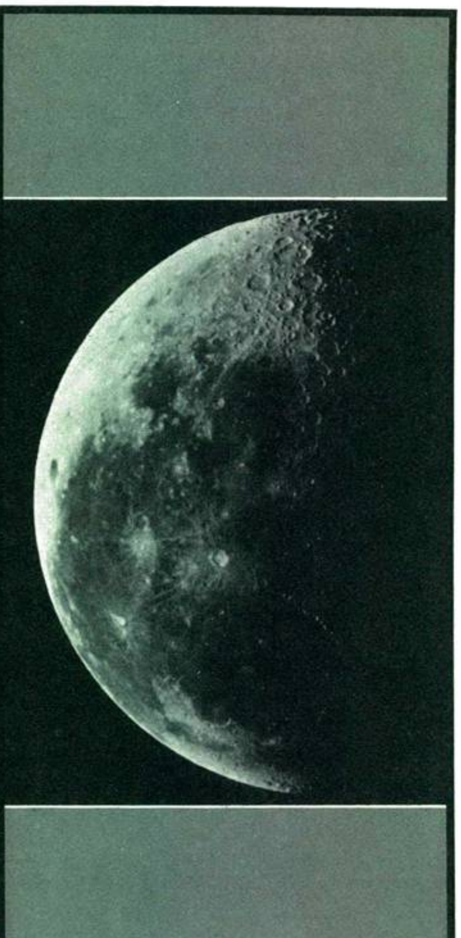
The effective focal length of the whole optical system (EFL) is the focal length of the telescope times the



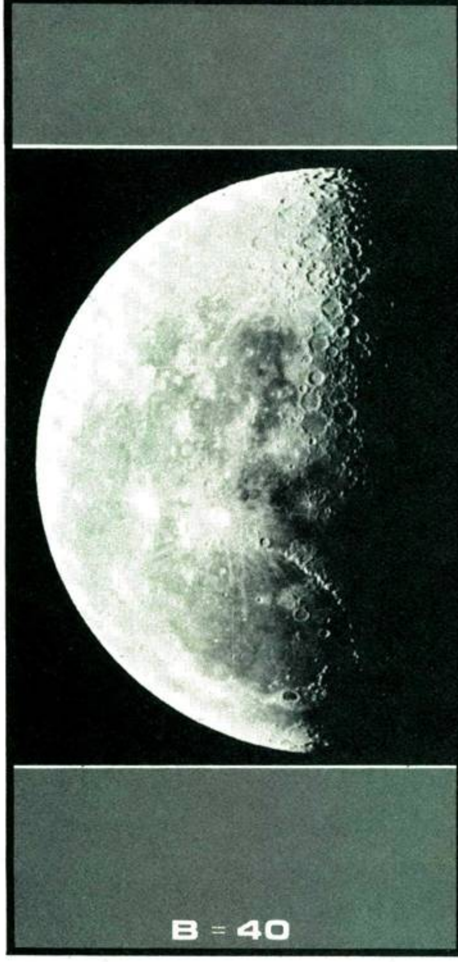
B = 320



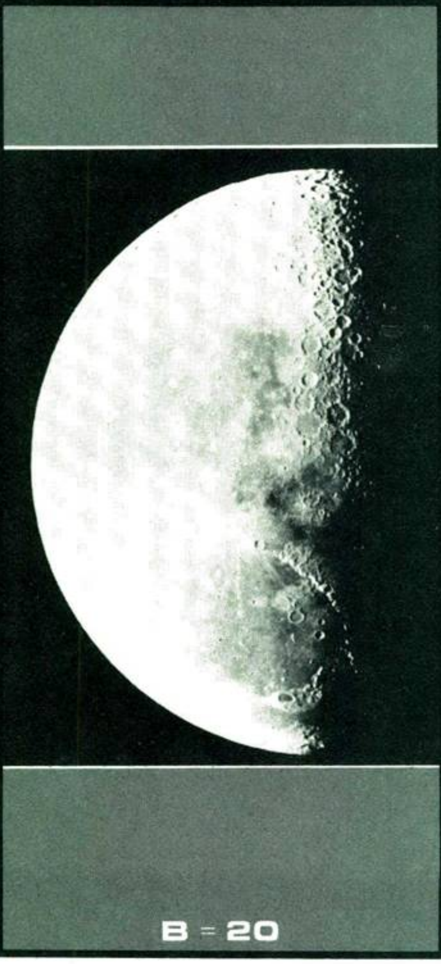
B = 160



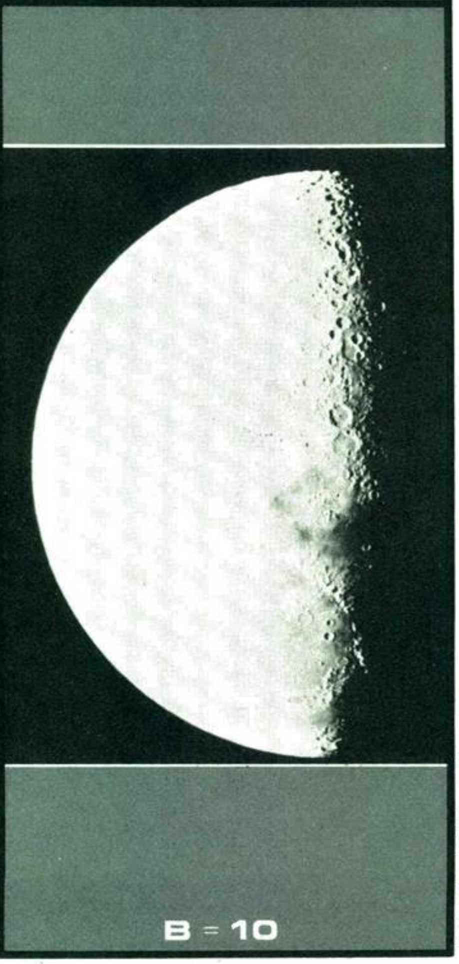
B = 80



B = 40



B = 20



B = 10

photos by Richard Berry

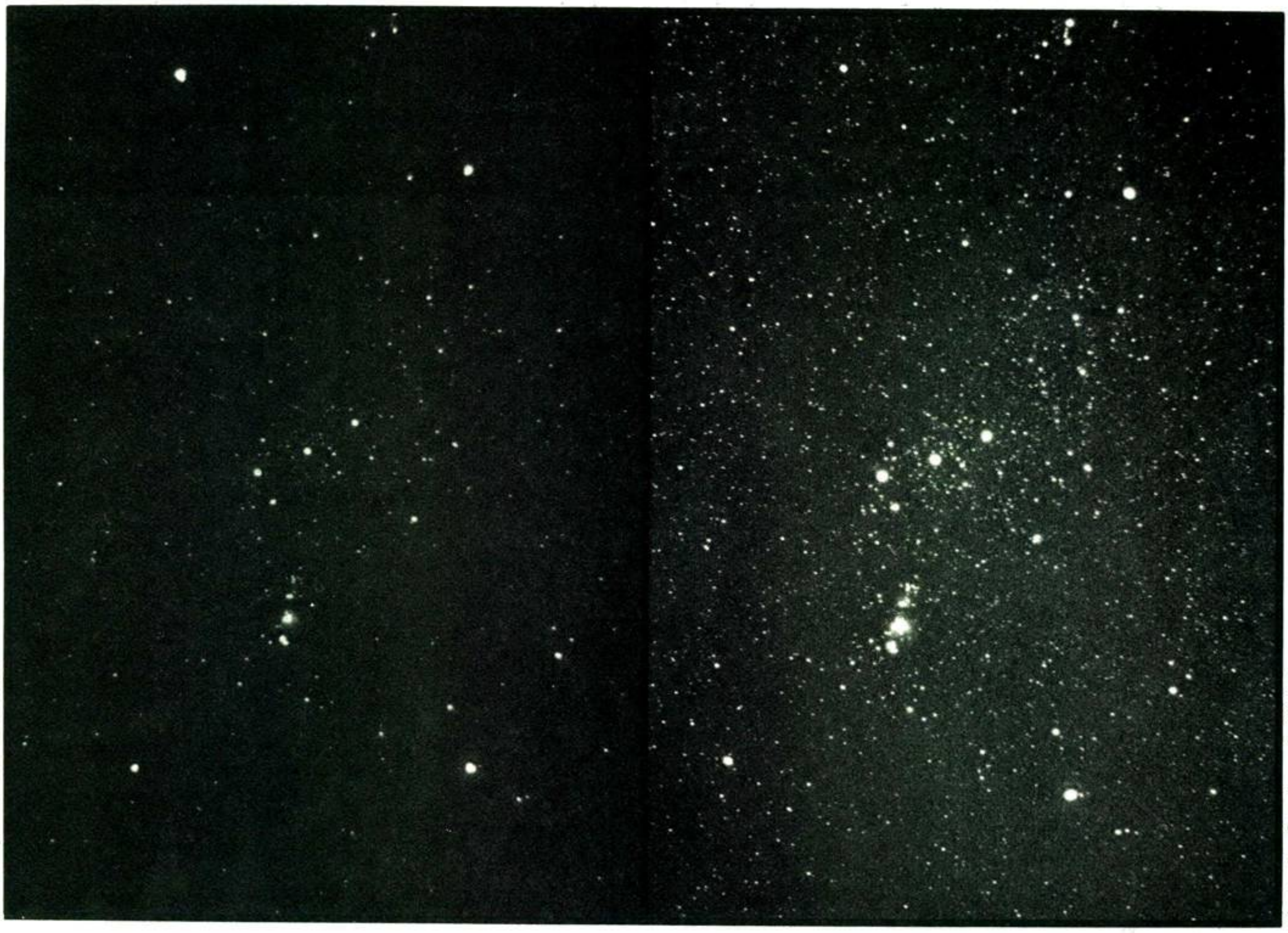


photo by Michael Elkevizth

photo by Stephen A. Walther

In many cases, there isn't any one "right" exposure. In the series at left, a short exposure (top left) captures limb detail, but little on the dark terminator. When you expose long (bottom right) for the terminator, you overexpose the limb. Above: At left, a short exposure shows about what the eye can see with a good dark sky. At right, a long exposure brings out lots of unseen stars.

magnification. The working f/ratio of the system (f) is the telescope f/ratio times the magnification.

$$EFL = M \times \text{original f.l.}$$

and

$$f = M \times \text{original f/ratio}$$

If the main telescope is a 6" f/8, this works out to an effective focal length of some 86 inches or 2200 mm. And the f/ratio is 1.8 x 8 or about f/14. Again, it's very simple.

The third system in general use is the *eyepiece projection* method, in which an eyepiece throws the image from the telescope into a lensless camera body. The camera body acts as a film holder and ground-glass focuser.

Once more, the best approach for finding the EFL and working f/ratio is to calculate the magnification of the projection system. To work this out, you must first measure how far the image is projected by the eyepiece.

Begin by attaching the photographic adapter (with eyepiece inserted) and camera body to the telescope. Measure the distance from the center of the eyepiece to the film plane in the camera. (This is usually marked — see your owner's manual.) Call this distance D.

The magnification is equal to distance (D) divided by the eyepiece focal length, minus 1:

$$M = (D \ / \ \text{eyepiece f.l.}) - 1$$

Knowing M, you can get the effective focal length and f/ratio. (Remember: EFL = M x original f.l., and f = M x original f/ratio.)

Suppose you want to use a Barlow instead of an ordinary eyepiece. What then?

Set up and measure the projected distance (D) from the center of the Barlow to the film plane. In this case, the formula changes to:

$$M = (D \ / \ \text{Barlow f.l.}) + 1$$

Otherwise, everything's the same. The focal lengths of Barlows and other negative lenses are commonly given as a negative number (for example, -109 mm). Ignore the minus sign — we've already taken care of it in the equation.

Knowing how to work out the effective focal length and working f/ratio for all the standard astrophotographic systems means you've conquered the trickiest part. Still, before you can get the correct exposure, you have to account for two more variables: film speed and subject brightness.

You control the film speed: it's the ASA rating printed on the box your film came in. Of course, you can choose any film you like, but in practice, you'll find the fast films — those with large ASA numbers — work best.

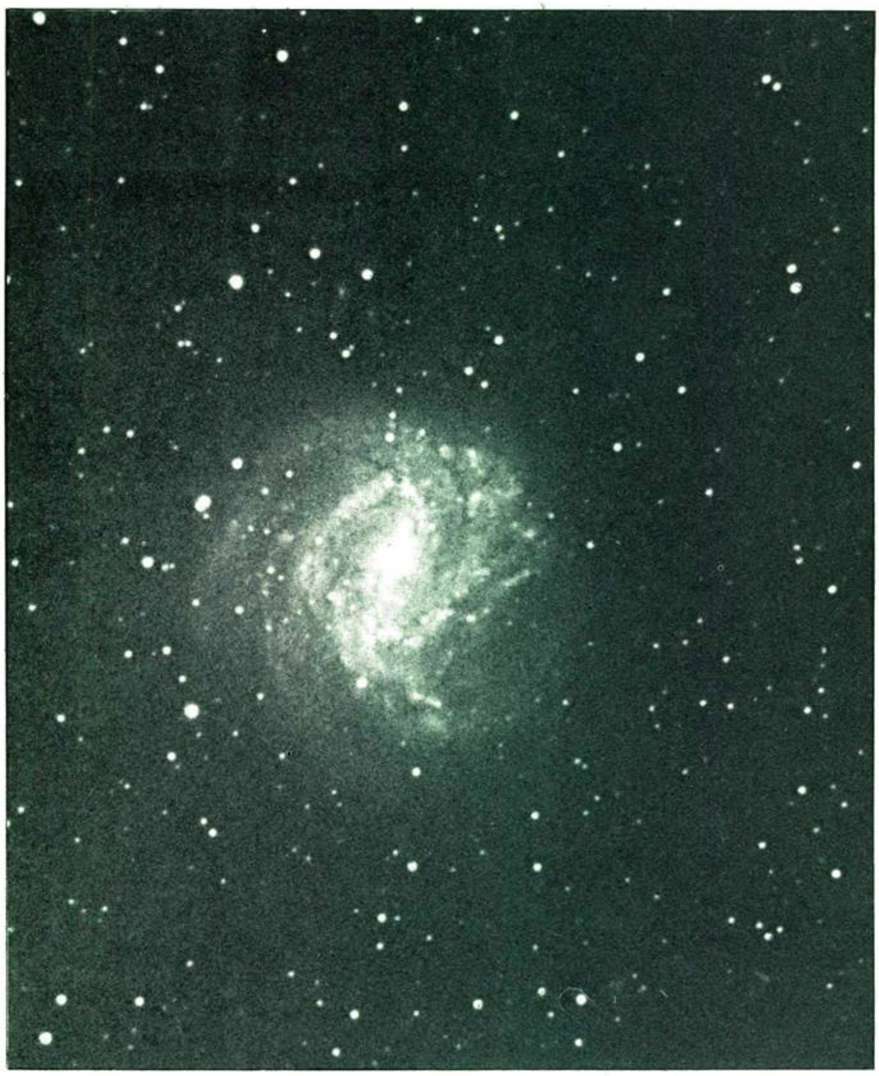
But what about the subject brightness — how do you allow for it? Luckily, this is simple, too. The f/ratio, film speed, subject brightness, and exposure time all tie together in one simple formula:

$$E = f^2 \ / \ (S \times B)$$

E is the exposure in seconds, f the working f/ratio, S the film's ASA

brightness (B) values of celestial objects

Terrestrial features:	
blue sky	1,000
summer scene	250
winter scene	100
inside room at night	2
Sun:	
disk	10,000,000
eclipse features	
prominences	100
inner corona	50
middle corona	5
outer corona	0.5
eclipse sky	0.01
horizon at eclipse	0.5
Moon:	
thin crescent	10
wide crescent	20
quarter phase	40
gibbous phase	80
full phase	200
Earthshine	0.001
eclipse features	
edge of penumbra	0.05
mid-totality	(varies) 0.005
Planets:	
Mercury	60
Venus	2,000
Mars	60
Jupiter	30
Saturn	10
Uranus	40
Deep-Sky Objects:	
core of Orion Nebula	0.001
most nebulae	0.0001
nucleus of M-31	0.0001
most galaxies	0.00001
Milky Way	0.00001



Small objects — like this spiral galaxy, M-83 — photograph best with eyepiece projection. Martin Germano used an 8-inch f/10 scope and an eyepiece that gave a 6x enlargement. The exposure was 50 minutes at f/60 on 103a-F.

speed, and B a "brightness constant" that varies from object to object. (In the box above, we've listed some tested values for B.)

For example, let's say you want to photograph crater details on the Moon at First Quarter. You've worked out the f/ratio for your system and it comes to f/20; your film is Plus-X. What's the exposure?

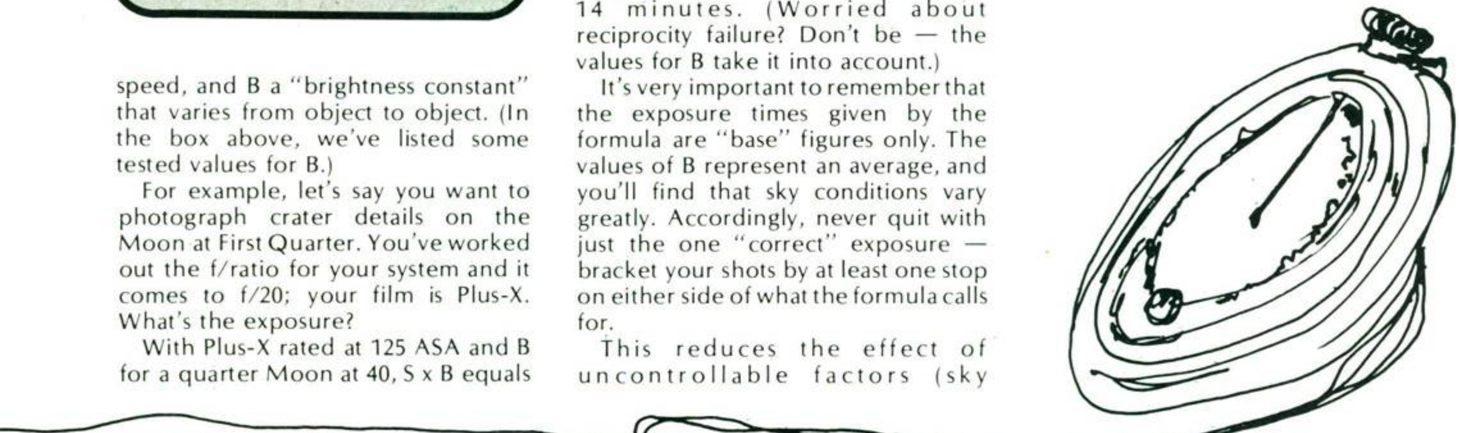
With Plus-X rated at 125 ASA and B for a quarter Moon at 40, S x B equals 5000; dividing 5000 into 20^2 (or 400) gives about 0.08. Thus the basic exposure should be 1/12.5 of a second — in practice, you'd give it 1/15 second. If you were using Tri-X or some other 400 ASA film, the exposure calculates out to be 1/40 second — so in practice, you'd try 1/30 second.

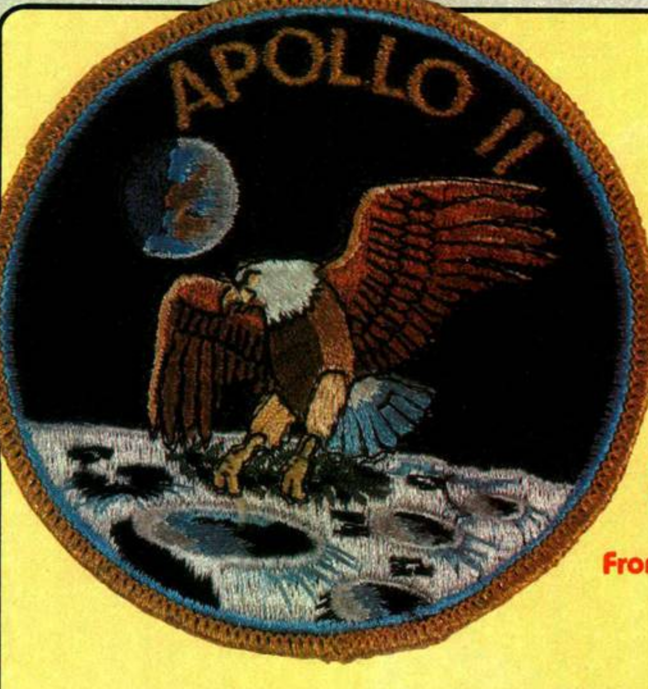
Or suppose you want to photograph the Milky Way (B = 0.00001) with a 50 mm f/1.8 lens and Ektachrome 400. What exposure do you use? Since 400 x 0.00001 equals 0.004, dividing this into 1.8^2 (or 3.24) gives 810 seconds — about 14 minutes. (Worried about reciprocity failure? Don't be — the values for B take it into account.)

It's very important to remember that the exposure times given by the formula are "base" figures only. The values of B represent an average, and you'll find that sky conditions vary greatly. Accordingly, never quit with just the one "correct" exposure — bracket your shots by at least one stop on either side of what the formula calls for.

This reduces the effect of uncontrollable factors (sky transparency, for example) on your photos. Moreover, you'll soon find that varying exposure times give you interestingly different views of the same object!

— *Robert Burnham*





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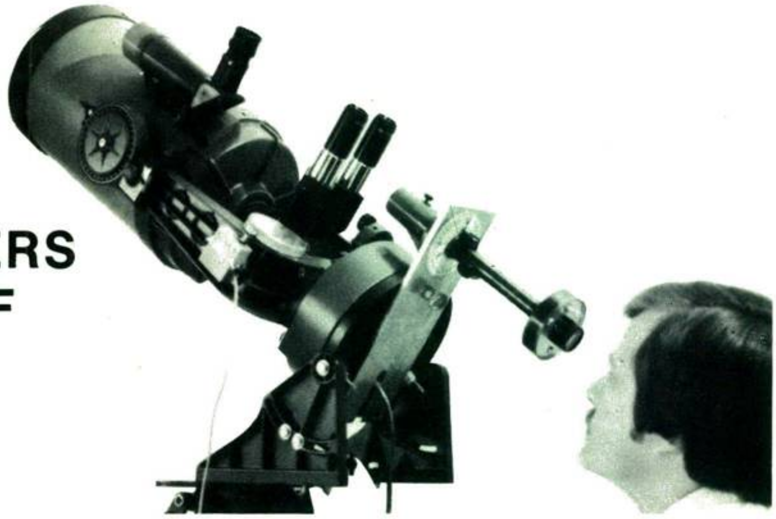

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AstroNews

Evidence for an Open Universe Expands

By probing superclusters of galaxies — the largest masses of matter visible in the universe — a University of California team has found strong new evidence that we live in an "open," ever-expanding universe.

An open universe contains too little mass for gravitational attraction to hold it together. This means that the galaxies in the universe — as they have for the last 15 billion or so years — would continue to push outward in time and space forever.

Such a cosmic model is favored by most astronomers. A minority view, however, favors a "closed" universe, which has a sufficient density (and therefore gravitational force) to slow down and reverse the outward expansion. Eventually, according to the closed-universe advocates, the galaxies will fall back together in an all-annihilating implosion, followed, perhaps, by another cosmic "Big Bang" explosion that will create a new universe and start a new cycle.

"The question is whether we exist in a unique universe, the only one we will ever have, or are just seeing one in a cycle of past and future universes," says Prof. Holland C. Ford of the UCLA astronomy department.

As one way to test the opposing models, Dr. Ford and his colleagues fixed their sights two billion light-years away on superclusters of galaxies. Participating in the three-year-long project were space physicist Richard J. Harms of UC San Diego, UCLA graduate student Robin Ciardullo, and Frank Bartok of the Martin Marietta Corporation in Denver.

Superclusters stand at the top of the cosmic hierarchy. Each supercluster contains as many as seven smaller clusters, each of which, in turn, may consist of several hundred separate galaxies. Our Milky Way Galaxy, for instance, is part of the Local Group — a fairly modest cluster which also includes M-31 in Andromeda and about two dozen lesser galaxies.

"Superclusters are the largest scale objects we can see well enough to determine their structure, and they are among the densest regions in the universe," says Dr. Ford. The four superclusters analyzed by the scientists with the three-meter (120-inch) telescope at UC's Lick Observatory measure 300 million light-years across.

The team members concentrated on measuring the velocities at which specific clusters of galaxies were moving away from the observer to determine their relative motions within the superclusters. These motions, in turn, reveal the mass and therefore the density of the superclusters.

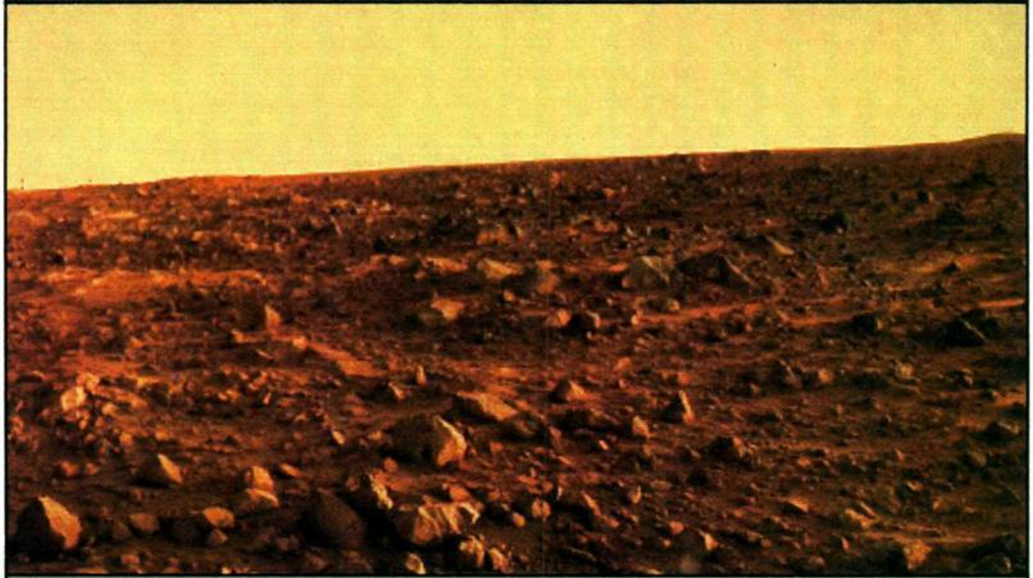
The researchers found that the universe holds only one-tenth the amount of matter required to reverse the constant expansion postulated in the open universe model, according to Dr. Ford.

At the same time, the team deduced that the superclusters are slowing down and moving at about half the speed of matter elsewhere in the universe. In a few billion years, Dr. Ford believes, the superclusters will reach their maximum volume, then slowly contract, and eventually reach a point of equilibrium — neither expanding nor contracting.

While such a development might seem to strengthen the case for a contracting or closed universe, Dr. Ford arrives at a different conclusion.

"Actually, the supercluster

Space Photographs Displayed



The most comprehensive exhibition to date of space exploration photographs will be displayed at the Grey Art Gallery and Study Center of New York University from June 23 through July 31, 1981. The 185 photographs in the exhibition present the full range of mankind's attempts to document and analyze the heavens through photography — from early 19th century meteorological experiments in France and England through the recent Voyager shots of Saturn.

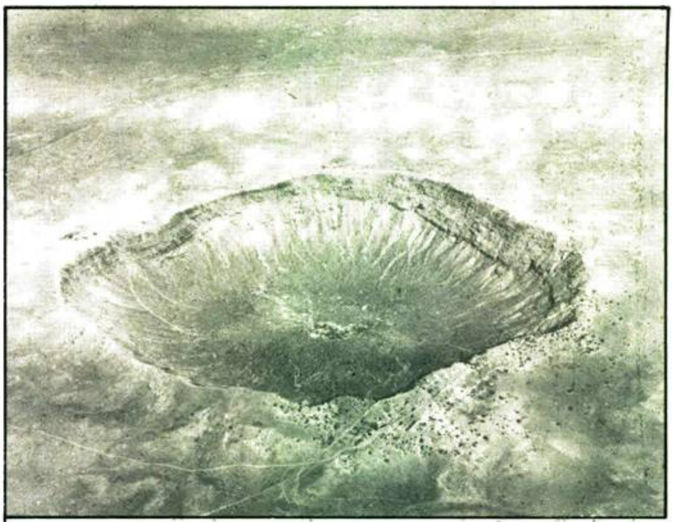
"The Photography of Space Exploration" has been organized with the cooperation of NASA and the Jet Propulsion Laboratory in Pasadena, California, and is sponsored by the National Endowment for the Arts. The major portion of the exhibition features photographs from the lunar landings compiled by the Space Science Data Center, space shots of Mars and Mercury from the Mariner series of 1972 as well as the later Viking Lander and Orbiter views of Mars, Voyager shots of Jupiter and Saturn, and photos of Venus taken by the Pioneer probe. Most of the photographs have never been seen by the public.

These space photographs, originally taken for the sake of scientific and engineering data, are visually compelling and occupy a unique place in the history of photography. They give evidence of a new frontier and are proof of the remarkable power of photography to travel in advance of mankind. The exhibition will be accompanied by an illustrated catalog, available by mail from the Gallery.

regions are 10 to 70 times denser than the 'empty volumes' which make up most of the universe," he says. "Although there are other ways to interpret the data, our deduction is that while some superclusters may contract, the universe around them will continue to expand."

Dr. Ford gives much of the credit for the research results to a newly-developed image tube spectrograph that enabled the UCLA astronomers to analyze the spectral lines of objects so distant that it had taken their light some two billion years to reach Earth. The spectral absorption lines provide the primary clues for fixing the velocities, densities, and other characteristics of the galaxies.

The four scientists are currently designing an even more sophisticated instrument, the faint object spectrograph. This spectrograph is slated to go into orbit with the Space Telescope in four or five years, riding aboard a space shuttle.



The Arizona Meteor Crater

Official U.S. Air Force Photo

Did a Meteor Kill the Dinosaurs?

A scenario for the catastrophic extinction of the dinosaurs by an immense meteor impact 65 million years ago (see "Extraterrestrial Climate Threats," ASTRONOMY, August 1980, and "The Fallen Sky," ASTRONOMY, April 1981) has been unfolded by two California Institute of Technology geophysicists. Their computer simulations reveal how a postulated 8 to 12 mile diameter meteorite weighing one trillion tons would have affected the Earth upon impact, releasing the energy equivalent of a billion megatons of TNT.

Their studies showed that the meteorite may well have killed off the dinosaurs upon impact with a flash of heat great enough to raise almost instantaneously — by about 10° — the temperature of Earth's atmosphere. The flash could also have raised the temperature of the ocean's upper layer by several degrees, destroying the large marine reptiles and other species, and drastically affecting the marine food chain. Smaller animals, including the primitive mammals that eventually evolved to become *Homo sapiens*, would have survived. According to the scientists, the heat blast explanation for the dinosaur's demise may prove more satisfactory than theories that dust from a meteor impact obscured the Sun for many years.

The scientists, Professor of Geophysics Thomas J. Ahrens and Visiting Associate in Planetary Science John D. O'Keefe, described their studies in a paper delivered recently at the Lunar and Planetary Science Conference in Houston, Texas. The Caltech scientists specialize in developing computer models for the impacts of asteroids and comets on the Earth, the Moon, and other planets.

The theory that a huge meteorite was responsible for the sudden and mysterious demise of the dinosaurs and many other species 65 million years ago was first proposed by physicist Luis Alvarez and his colleagues at the University of California at Berkeley. In a paper in the June 6, 1980 *Science*, they reported the discovery that a clay layer marking the boundary between the Cretaceous and Tertiary periods about 65 million years ago was enriched in certain noble metals — gold, platinum, and iridium, among others. This enrichment ranged from 5 to 1,000 times the average concentration found in the Earth's crust, and it was later found to exist at many spots throughout the world. The pattern of occurrence of these metals is similar to that found in certain stony and iron meteorites, and is different from the ratio of these elements found in terrestrial deposits of the metals.

Alvarez and his colleagues proposed that the enrichment and its pattern was strong evidence that a large meteorite had impacted Earth 65 million years ago, and that the dust cloud raised had obliterated the Sun for several years, causing the worldwide extinction. The Berkeley researchers were able to deduce the size of the meteorite — from 8 to 12 miles in diameter — from the worldwide abundance of the noble metals in the clay layer.

Assuming a meteorite of that diameter, Ahrens and O'Keefe computed the distribution of impact energy between heat and kinetic energy of the fragments of the meteorite and the Earth's surface. They studied the depth of penetration of several kinds of meteorites — including solid silicate, iron, and ice — into the atmosphere, ocean, and Earth. They also calculated the trajectories and energy contents of the debris or ejecta cloud produced upon impact at speeds fom 5 to 72 kilometers per second.

According to the scientists, the meteorite would have lost little of its energy in its trip through the atmosphere and released the greatest portion when it hit the Earth. In addition, a ten-mile meteorite would have plowed through even the deepest part of the ocean like a "bullet through a mud puddle." Thus, the difference in the effects of a land versus a water impact was insignificant.

By far, the major release of energy to the atmosphere was from the low-altitude ejected material spewed from the impact area. The extent of this heating could have been enough to support the theory of University of Miami paleontologist Cesare Emiliani that the dinosaurs could have been killed by a sudden worldwide temperature rise, rather than a Sun-obscuring dust cloud.

According to Dr. Ahrens, the most efficient heat transfer would have been produced by a comet — essentially a fluffy snowball — which would have flashed into steam upon impact. However, he noted, the question of whether the object was a comet or a denser rocky asteroid is still open. Experts on near-Earth objects have postulated that only about one-third of the objects impacting Earth over geological time are cometary, reducing the likelihood of a comet encounter.

But a problem arose when the debris-laden clay sediments examined throughout the world contained high concentrations of meteoritic material — up to 21 percent — while debris surrounding craters from other meteorite impacts on Earth contain only up to about 2 percent of meteorite material. The Caltech researchers' computer calculations showed, however, that, although a 10-mile wide meteorite would take a minute or more to blast out its 100-mile-diameter crater, during the first few seconds of impact, debris heavily laden with meteoritic material

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AstroNews

would be lofted from 10 to 100 miles into the atmosphere. This fine dust, representing about 10 percent of the meteorite's mass, would spread throughout the atmosphere at high altitudes and sift down onto the Earth.

When Strange Worlds Collide

The Crab Nebula pulsar

Lick Observatory

Could the intense point-source bursts of gamma rays sometimes observed by astrophysicists be caused by collisions between asteroidal bodies and neutron stars? Two scientists at the Los Alamos Scientific Laboratory think it's possible, and point to a gamma ray burst event detected on March 5, 1979 as an example of such a collision.

Michael Newman and Arthur Cox, writing in a recent issue of the *Astrophysical Journal*, say that statistically such collisions are quite possible, and that gravitational and thermal energy released in such a collision would cause a gamma ray flux of the intensity observed in the March 5 event.

The two give the following scenario: an asteroid of about one kilometer radius and with a mass of 100,000 million kilograms approaches a neutron star of 10 kilometers radius and one solar mass. When the asteroid gets within 100,000 km of the neutron star, it is torn to pieces by tidal forces. Most of the asteroid is turned into a fluid-like funnel about 100 km long and only 10 to 100 meters wide and hits the star's surface within seconds. The impace releases gravitational and thermal energy that's transformed into an intense burst of gamma rays.

Meanwhile, what's left of the asteroid spirals down the neutron star's magnetic field lines onto the magnetic poles, causing many short X-ray bursts that sweep across the sky as the star's rotation swings the magnetic pole "hot spots" around.

Newman and Cox note that no gamma ray bursts have yet been spotted coming from any of the 300 or so known neutron stars. The March 5, 1979 event may have originated in a supernova remnant called N-49 located in the Large Magellanic Cloud, but there's no known neutron star or pulsar associated with N-49. If the Newman and Cox calculations are right, there's a one in a hundred chance that observed gamma ray bursts will come from a known pulsar, and they predict such an observation will eventually be made.

Fossil Meteorite "Re"-Discovered

Two Swedish scientists, a geologist and paleontologist, have made the first positive identification of a fossilized stony meteorite.

Per Thorslund and Frans Wickman reported in a recent issue of *Nature* that the 10-centimeter-wide object, found in 1952 in a limestone slab from a quarry in central Sweden, has a terrestrial age of about 463 million years.

When Thorslund first examined it 29 years ago, he thought the object was an artifact created by ancient algae. In 1979 he and Wickman re-examined it and found microscopic chondrules, proving it to be a chondritic meteorite.

The meteorite is indeed a fossil: nearly all the original minerals have been replaced by terrestrial compounds, mostly calcite and barite.

Most astonishing, though, is what the two researchers found entangled with the meteorite — a fossilized snail-like creature. It seems the meteorite struck the snail on impact — and killed it!

The Most Distant Galaxies

Astronomers from California and Arizona have identified, and measured some properties of a group of giant galaxies 10 billion light-years from Earth. The previous "farthest out" galaxies were reported six years ago at a distance of about eight billion light-years. The new discovery means that the observable universe has become considerably larger and astronomers have, for the first time, looked more than half-way back in time toward the moment that many believe marks the beginning of the universe.

The scientists, who reported their findings in the March 2 issue of the *Astrophysical Journal*, are Dr. Hyron Spinrad, professor of astronomy at the University of California at Berkeley; John Stauffer, a doctoral candidate in astronomy at Berkeley; and Dr. Harvey Butcher, astronomer at Kitt Peak National Observatory in Arizona.

Dr. Spinrad said it appears that these most distant galaxies are much larger than our Milky Way and that it would require a thousand billion stars like the Sun to give them their observed brightness. The Milky Way contains about 100 billion stars.

These stargroups have the largest redshifts ever detected in galaxies, which means they are moving away from Earth at enormous velocities. Both light and radio waves from the newly discovered galaxies have been traveling through space at about six trillion miles per year for some billion years. Even on the best astronomical photographs, these galaxies appear as tiny smudges.

The astronomers reported that even though the light had traveled 10 billion light-years, it has a "normal" look, indicating that stars in the newly discovered galaxies are probably not very different from the Sun and other stars in our own Milky Way. This is important, they added, because they are seeing and studying the distant galaxies as they were 10 billion years ago.

Evidence from the farthest galaxies strongly supports a theory suggesting that a primordial explosion or Big Bang occurred about 18 billion years ago and was followed within about two billion years by the formation of stars and galaxies from the expanding gases.

The discovery of these remote galaxies involved international cooperation among many researchers in both radio and optical astronomy. In a paper on the discovery, Dr. Spinrad and his colleagues report the measurement of two of the galaxies identified as 3C427.1 and 3C13 — numbers assigned in a sky survey of radio sources conducted over many years at Cambridge, England. Since they submitted their paper several months ago, Dr. Spinrad said, his group has measured two more galaxies about 10 billion light-years distant, increasing their confidence in both the findings and their interpretation.

According to astronomical theory, greater redshifts are evidence that objects are receding from the Earth at faster speeds — and these speeds in turn imply greater distances from Earth. In just two decades — from 1960 to 1980 — the observed size of the universe as seen from the Earth has doubled from five billion to 10 billion light-years.

"The technical means are becoming available to see objects at 20 to 30 percent greater distances," Dr. Spinrad said. "Newly forming galaxies, if they could be seen from distances up to 16 billion light-years...should be spectacularly luminous." Observations at such distances could provide important evidence to help answer the question of whether the universe is "open," and thus expanding indefinitely, or "closed" and fated for eventual inward collapse.

More for Mauna Kea?

Since 1968, the University of Hawaii-controlled astronomical research preserve atop 13,784-foot Mauna Kea on the "Big Island" of Hawaii has grown rapidly in size. Proposals now on the boards, though, could make this volcanic peak in the 50th state one of the most important land-based astronomical research centers in the world.

Current facilities at Mauna Kea include two 24-inch telescopes owned by the University of Hawaii's Institute for Astronomy, an 88-inch optical-infrared telescope also owned by the University, a 120-inch NASA infrared telescope, a second 120-inch infrared telescope owned by a consortium of French, Canadian, and U.S. institutions, and a 150-inch British infrared telescope.

With 51,100 square inches of light-gathering area, the instruments located at Mauna Kea constitute the largest concentration in the world.

Several other institutions with important projects are now seeking building sites at Mauna Kea. The National Radio Astronomy Observatory wants to build a 25-meter radio telescope for research into interstellar molecules and the organic matter that forms in dust clouds in space. The Vienna University Observatory wants to locate a 40-inch telescope there, and the California Institute of Technology wants to build a 10-meter National Science Foundation-funded radio telescope.

Still another project proposed for the Mauna Kea site is a $50-million optical telescope that the University of California would use as the principal tool for its astronomical research programs. This instrument would be the largest optical telescope in the world.

Any of these projects would raise Mauna Kea's scientific capability, but they could be diminished by the most ambitious proposal of all — the creation of a major national observatory utilizing "next generation" technology. The National Science Foundation is presently studying the comparative qualities of various sites in the country with the objective of building such an advanced observatory. Construction costs for this vast project are expected to run as high as $150-million, and Mauna Kea has been mentioned as the preferred site.

Mauna Kea observatories

Photo by Larry Kadooka

Surplus Solar Observatory

Something of an era is passing. At the Marshall Space Flight Center in Huntsville, Alabama, the back-up twin of the Apollo Telescope Mount — a part of Skylab that served as the nation's first manned astronomical observatory in space — has been declared "surplus" and made available for other uses. Some of the components, however, may yet fly in space.

The observatory was assembled at Marshall in the late 1960s and early '70s, and is identical to the payload flown as a part of Skylab from 1973-74. It has been kept in storage at Marshall for nearly 10 years, and now is out of date.

"We had to have a back-up observatory when it was first designed in the mid-1960s," said Herman Gierow, director of the Advanced Systems Office at Marshall, "because space exploration was still new to us, and we would have been taking a great risk in not having a duplicate unit in case something happened to the original. But 15 years have passed since then, and technology has advanced so rapidly that the observatory is antiquated by today's standards."

Once described by a prominent astronomer as "one of the most important milestones in the history of solar astrophysics," the orbiting observatory was an array of eight separate solar telescopes that observed the Sun in X-ray, ultraviolet, and visible light. Weighing 25,000 pounds, it was launched with Skylab on May 14, 1973, and was operational throughout the three manned missions that were to follow. When the last crew returned to Earth on Feb. 8, 1974, the cameras of the observatory had taken over 150,000 successful exposures.

The Marshall team of engineers that assembled the cluster of telescopes used state-of-the-art equipment. Each of its instruments, provided by U.S. scientific institutions, was the most advanced of its type ever to be flown in space at that time, and each took full advantage of the unique conditions of Skylab's orbit. None of the instruments would have served any purpose on the ground or even in a mountain-top observatory.

The X-ray and ultraviolet instruments needed the altitude of Skylab's orbit to get above the atmosphere, which completely absorbs radiation in these regions. This ideal condition enabled the X-ray instruments to peer at the complete corona of the Sun — not just at its edge, as with observations in visible light. In addition, a visible light coronagraph took advantage of the negligible sky brightness at Skylab's altitude and enabled observation of the Sun's thin outer corona. And the ultraviolet instruments provided a look at the mysterious layerings of the Sun and all their varying temperatures, densities and chemical compositions.

"The Apollo Telescope Mount was an incredible boon to solar observation," said Gierow, "but as advanced as it was, we have even better equipment today to send into space. We kept the instruments in storage all these years because we felt there might be a future need for them, but none materialized — at least not for the entire cluster of telescopes as it's presently structured. We want to remove the instruments and put them to use individually. For example, there's a good possibility some elements of them may be flown aboard Spacelab." Spacelab is the orbiting laboratory scheduled for its first mission in the Space Shuttle.

After removal of the instruments, other parts of the observatory may be dismantled and put to use. All NASA centers and all Federal agencies will be screened by the Marshall Center to determine who will receive the components. Ultimately, some of the observatory's equipment could be sold to the public through government auction.

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REVIEWS

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The Coulter CT-100 is a unique piece of equipment — a 4¼" f/4 (f/3.5 in slightly earlier models) Newtonian that collapses into a 5½" x 7½" x 7" carrying case and weighs less than five pounds. It has a ¼-20 threaded socket to fit on a standard camera tripod and accepts standard 1¼" eyepieces.

The secret of the telescope's compactness is that in place of a tube, it has two detachable sections: one containing the primary mirror; the other, the diagonal and eyepiece holder. Each clamps onto a rigid aluminum bar.

Slide them along the bar, and you can make large variations in the position of the prime focus relative to the eyepiece holder, making the CT-100 one of the few Newtonians that will accept a Porro-prism image erector.

For storage, the two detachable sections go into the carrying case, and the aluminum bar bolts to its shoulder strap. Set-up or knock-down takes less than five minutes.

At low powers of 15 to 20x, the CT-100 is ideal for wide-field sweeping and observing clusters, nebulae, and galaxies. It is particularly good at picking up faint, diffuse objects. For instance, one very clear evening last January, I aimed my CT-100 at the Pleiades and found the Merope nebulosity downright conspicuous and with hints of streakiness. I then looked at the region of Zeta Orionis and clearly saw nebulosity extending to the northeast of the star. A closer look revealed another much fainter nebula extending to the south and (just at the limit of visibility) a dark notch — the Horsehead — seldom visible in telescopes of small aperture. This was exceptional, of course, but is an example of what the CT-100 is best suited for.

On the other hand, the CT-100 is far from ideal for lunar and planetary observations. The images show a certain lack of crispness, even at 30x. I can think of two reasons for this.

First, the placement of the open tube so close to the observer's body means that the light path is usually full of warm, turbulent air. Second, and more important, the sharply converging cone of light from an f/3.5 or f/4 primary seems to bring out the worst in any eyepiece.

It is *not* due to defective primary optics — at least so far as I can tell from a rough-and-ready Foucault test I performed with starlight. It seems to be spherical aberration that varies from eyepiece to eyepiece. (Masking the aperture down to f/4.5 or more helps considerably.)

I also got somewhat better results with a Meade 18 mm orthoscopic eyepiece than with the Kellners supplied by Coulter, but my best advice is this: if you want to observe planets, you need Coulter's f/8 conversion kit (consisting of an f/8 mirror assembly and a suitably longer aluminum bar) or their kit for building an f/8 telescope, rather than the CT-100 by itself.

The CT-100 is also not a prime choice for photography, because the coma-free image from an f/4 paraboloid is only about half an inch in diameter. Nor is it well suited for terrestrial observing — partly because stray light gets in the open tube and partly because of the soft images just mentioned. I don't mean that the CT-100 is useless in these applications — only that a telephoto lens or spotting scope would be a better buy if you want a telescope for photography or birdwatching.

Still, the compactness and low price of the CT-100 are strong selling points. And it costs less to buy a complete CT-100 than to convert a Celestron or similar telescope to rich-field operation (either by a telecompressor lens or with a 2-inch eyepiece and diagonal). The CT-100 probably reaches its greatest usefulness not as a first telescope for beginners, but as a second telescope for advanced observers who already have instruments with a long focal length.
Michael Covington.

The Ancient Sun
R.O. Pepin, J.A. Eddy, and R.B. Merrill, eds.
581 pages, hardcover, $56
Pergamon Press (1980)

Historical records have allowed astronomers to peek into the past behavior of the Sun, but to push more than a few millennia back, some other method is needed. Accordingly, rocks from the Earth, Moon, and meteorites have been studied carefully to see what clues they offer. This volume prints the papers given at a conference in October 1979.

The Search for Gravity Waves
P.C.W. Davies
144 pages, hardcover, $19.95
Cambridge University Press (1980)

Gravity waves potentially are another one of those "windows into the cosmos" — like infrared, radio, and X-rays — which have increased our understanding of the universe so much in the last 30 years. Yet while their existence is pretty well grounded in theory, they have yet to be detected unambiguously.

Davies' book explores the problem as well as acquainting the reader with the theoretical background and the experimental efforts involved in detecting them. (Some degree of mathematical expertise is called for, but isn't essential.)

Rainbows, Halos, and Glories
Robert Greenler
195 pages, hardcover, $24.95
Cambridge University Press (1980)

To understand and so become aware
And, thus, mine beauty from the/
crystaled air.

With these lines in his preface, Robert Greenler sets the tone for a book that is both a masterpiece of explanation and an inspired expression of his own delight in exploring the natural world.

In his first chapter (about rainbows), Greenler presents the refractive, reflective, and interference phenomena required to understand the striking shapes and subtle colors that water droplets and ice crystals produce in the sky. You need little previous knowledge of optics to follow his explanation, yet the presentation is engaging enough to hold an expert's interest.

Greenler draws our attention to strange rainbows: red, white, rising, lunar, infrared, and others. Best of all, he points out a wealth of things to watch for in an ordinary bow.

For example, just inside the main rainbow, a series of faint arcs or *supernumerary* bows often shows up. Interference causes these supernumeraries, and their appearance and spacing yield clues about the size range of the droplets producing the rainbow. They also serve as an excellent natural demonstration of the wave properties of light.

Greenler's first chapter and five of the six that follow end with photographic puzzles for the reader to solve. For his first, the author presents a photo of a frosty landscape surmounted by a beautiful rainbow. We are left to ponder what makes the picture unusual and to seek an explanation. All these "formal" puzzles are solved in an appendix, but some of the informal challenges throughout the text are true research problems, still unsolved.

The chapters about ice crystal displays are the most extensive, and reflect Greenler's research interests. To analyze the complex halos, pillars, sun dogs (parhelions), arcs, and shadings that are part of an ice crystal display, he uses computer simulation. The computer models can be made to mimic the forms found in the author's photos and engravings, and therefore help in understanding the physical processes at work. However, some phenomena on record have no explanation, and Greenler invites further observations.

Making such observations is not terribly complicated: for the most part, you'll need simple equipment, usually a 35mm camera and an inexpensive fish-eye attachment. The fish-eye attachment will allow you to "capture" entire rainbows and sky-filling ice crystal arcs, while an ordinary lens would not.

Chapter five is devoted to light and color found in the sky and clouds. It ranges from the blue of the sky through cloud colors to the effect of the Moon's shadow on the appearance of the sky during a total solar eclipse. In chapter six (about diffraction effects and coronas producing rings around the Moon), Greenler describes the specter of the Brocken (p. 143):

"Now you stand on the mountain top, looking out over a world largely hidden from your view by the clouds. As you survey your surroundings, you see a giant shadow figure standing in the cloud mist. The apparition moves as you move and is clearly some magnified projection of yourself in this very special place. Around its head — your head — you see a series of brilliantly colored halos."

The giant shadow is a cloud projection effect and the rings are caused by diffraction. It's no longer necessary to scale a misty peak to see the specter, for similar rings often surround the shadow of an aircraft

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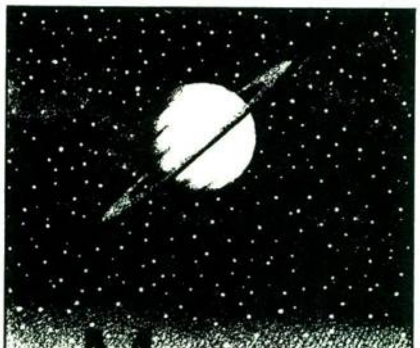

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Other astronomically popular *Harvard Books on Astronomy* titles include: Frontiers of Astrophysics, Eugene H. Avrett, Editor, at $10.00 paper, $25.00 cloth; and Stars and Clusters, Cecilia Payne-Gaposchkin at $22.50.

Harvard University Press
Cambridge, MA 02138

cast upon cloud tops.

The final chapter, "Atmospheric refraction: mirages, twinkling stars, and the green flash," offers an experiment we stargazers can try when the stars are twinkling too violently for clear telescopic viewing: Observe a twinkling star, with one eye closed, through a pair of binoculars. Wave the binoculars around in a small circle, at the rate of one or two circles per second to smear out the star's image. The smear becomes a line of bright, colored spots, each spot representing a distinct refractive event in our boiling atmosphere.

The book's 105 color plates are reproduced about snapshot size — adequate to show the details described in the text — though many of the photographs are so striking they deserve enlargement. For the enthusiastic, color slides of the plates are available from Mallman Scientific Co., 20250 Jeffers Drive, New Berlin, WI 53151. Most pages of the text are accompanied by black and white photos or simple line drawings.

Footnote sources (listed at the end of the book) serve as an excellent bibliography. Greenler also recommends some general reference books and articles, but his book reviews the subject so thoroughly, it could become the standard work.

The clear prose and thought-provoking content of *Rainbows, Halos, and Glories* are complemented by crisp typography and a clean layout. It's truly a work that will bring a great deal of enjoyment to those who delight in exploring all the subtleties and splendors of our natural world. *William Peters.*

Space
Anthony Feldman
336 pages, hardcover, $19.95
Facts on File (1980)

The ten chapters of this colorfully illustrated book cover such topics as the birth of astronomy, the Sun and stars, the solar system, galaxies, origin of the universe, man in space, life in the universe. The intended readership is general.

The New Face of Mars
V.A. Firsoff
164 pages, hardcover, £4.95
Ian Henry Publications (1980)
[available from: State Mutual Book Service, 521 Fifth Ave., New York, NY 10017]

This book provides, for the general reader, an interesting, readable, and detailed summary of what has been learned about Mars by means of the Mariner and Viking probes.

Arthur C. Clarke's Mysterious World
Simon Welfare & John Fairley
217 pages, hardcover, $17.95
A&W Publishers (1980)

This curious book presents a vast assortment of natural oddities and events, like the Loch Ness Monster, UFOs, yetis, etc. Arthur C. Clarke, a well-known science fact and fiction writer, introduces the collection and provides a comment at the end of each chapter. Anyone who relishes those fine, impenetrable mysteries that "science cannot explain" will enjoy the book greatly — and perhaps take a crack at working out an explanation for himself. It's all in good fun.

But when I see a photo like the one on page 207, I cannot help wondering about the credentials of the authors. The photo in question, having a minimal caption with few facts and no supporting text, is supposed to show ball lightning caught in the act. But as any camera buff will notice immediately, it is only a time-exposure photo of a streetlight. The "ball lightning" came about when the photographer, accidently or intentionally, moved the camera during the exposure. The streetlight image, clearly showing the pulse of the electric current lighting it, moves off out of the frame in a crooked, wavy line.

Incredibly, *Nature* (a world-renowned scientific journal) published this same photo on its cover several years ago, labeling it as ball lightning. The error was immediately pointed out to them by a number of readers, and the magazine issued a correction shortly thereafter. Why hasn't this photo disappeared into well-deserved oblivion? I suppose all's fair in love and mystery mongering, but I'd like to think this is not typical of the rest of the book's evidence! *Robert Burnham.*

White Dwarfs - Black Holes
Roman & Hannelore Sexl
203 pages, hardcover, $13.50
Academic Press (1979)

Subtitled "an introduction to relativistic astrophysics," the Sexls' book expects the reader to have some physics background and a good knowledge of calculus.

Non-Solar Gamma-Rays
R. Cowsik & R.D. Wills, eds.
276 pages, hardcover, $50
Pergamon Press (1980)

This book records the 27 papers given at a 1979 COSPAR symposium — largely experiment results, plus some papers on theoretical work.

Riddles of the Stone Age
Jean McMann
160 pages, hardcover, $16.95
Thames and Hudson (1980)

Subtitled "rock carvings of ancient Europe," this book's astronomical point of contact lies in its splendid duotone photographs of megalithic structures. Not all are astronomically aligned but each is fascinating.

The Large-Scale Structure of the Universe
P.J.E. Peebles
422 pages, hardcover, $30; paperback, $9.95
Princeton University Press (1980)

This book, intended for the professional astronomer, develops mathematical models for describing the overall shape and structure of the universe. Beginning with a history of the subject (basically since 1927), he continues with a discussion of Newtonian approximations. After dealing with the dynamics of galaxies and clusters of them, he finishes with a relativistic treatment of the expanding universe.

Space Research
M.J. Rycroft, editor
285 pages, hardcover, $62.50
Pergamon Press (1980)

Space Research reprints the papers given at a COSPAR meeting of planetary scientists in 1979. The 50 technical contributions are arranged in four general categories: Earth's neutral atmosphere, Earth's plasma envelope, planetary science, and astronomy.

Black Holes and Warped Spacetime
William J. Kaufmann, III
221 pages, $14 (hardcover), $7.50 (paperback)
W.H. Freeman (1979)

These eternally popular topics (and by force of inclusion, relativity) are explained lucidly to the interested layman by a well-known astronomy writer.

The Lunar Highlands Crust
Lunar and Planetary Institute, compilers
505 pages, hardcover, $52
Pergamon Press (1980)

This book records the papers given at a conference in mid-November 1979. Although it's aimed at the professional planetary scientist, anyone with a bent for lunar geology will enjoy at least browsing through it.

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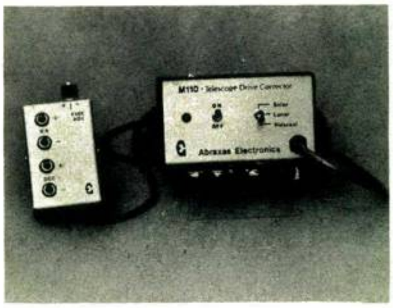

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FLARE STARS

by Anthony J. Nicastro

How deceptive is the tranquility of the night sky. Far removed from the systems upon which we gaze, we strain with optics and electronics to catch the fits and starts of the heavens. We detect a whisper, not a shout, and so project a sense of calm and ease to the entire universe — misled by our distant point of view.

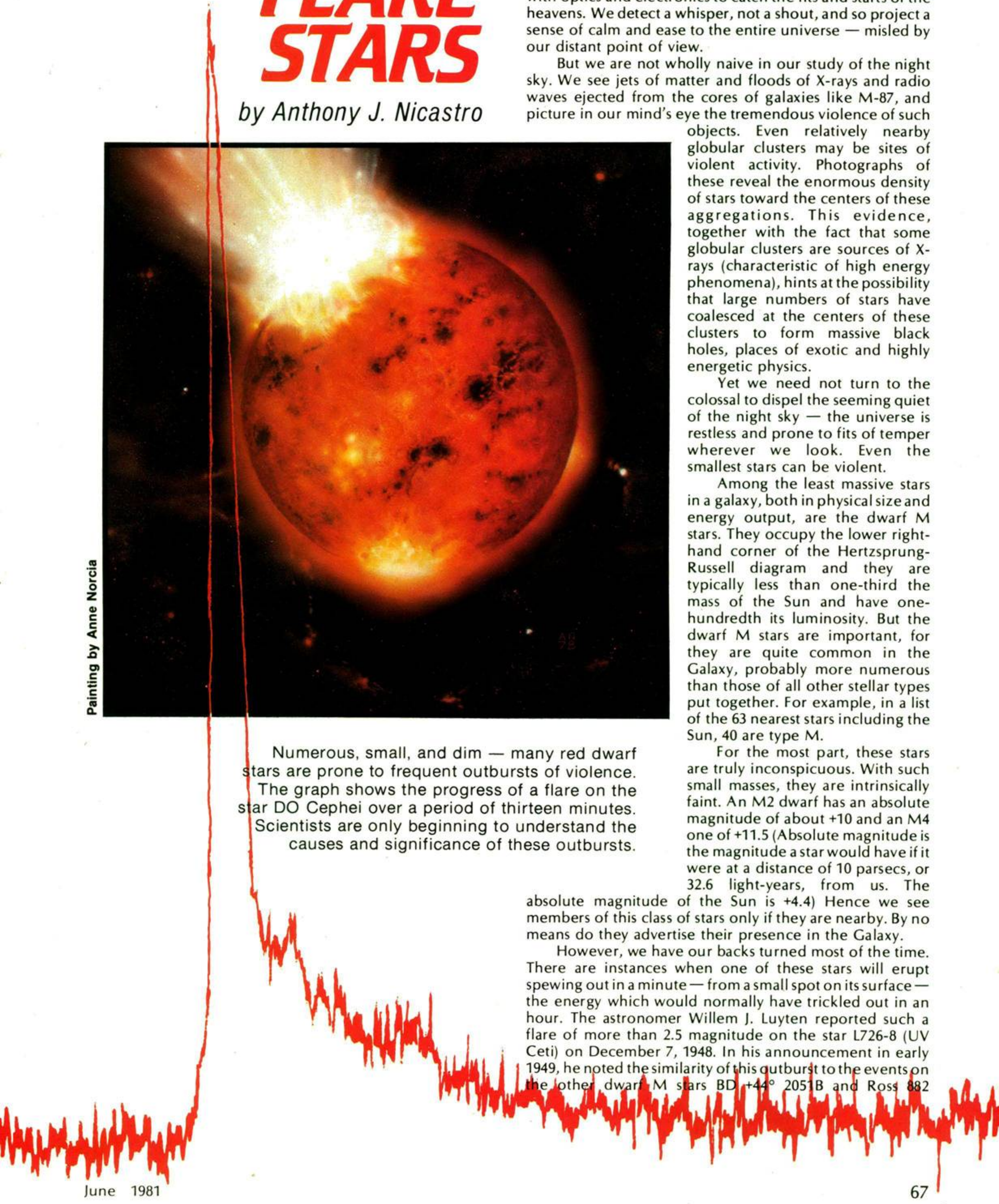
But we are not wholly naive in our study of the night sky. We see jets of matter and floods of X-rays and radio waves ejected from the cores of galaxies like M-87, and picture in our mind's eye the tremendous violence of such objects. Even relatively nearby globular clusters may be sites of violent activity. Photographs of these reveal the enormous density of stars toward the centers of these aggregations. This evidence, together with the fact that some globular clusters are sources of X-rays (characteristic of high energy phenomena), hints at the possibility that large numbers of stars have coalesced at the centers of these clusters to form massive black holes, places of exotic and highly energetic physics.

Yet we need not turn to the colossal to dispel the seeming quiet of the night sky — the universe is restless and prone to fits of temper wherever we look. Even the smallest stars can be violent.

Among the least massive stars in a galaxy, both in physical size and energy output, are the dwarf M stars. They occupy the lower right-hand corner of the Hertzsprung-Russell diagram and they are typically less than one-third the mass of the Sun and have one-hundredth its luminosity. But the dwarf M stars are important, for they are quite common in the Galaxy, probably more numerous than those of all other stellar types put together. For example, in a list of the 63 nearest stars including the Sun, 40 are type M.

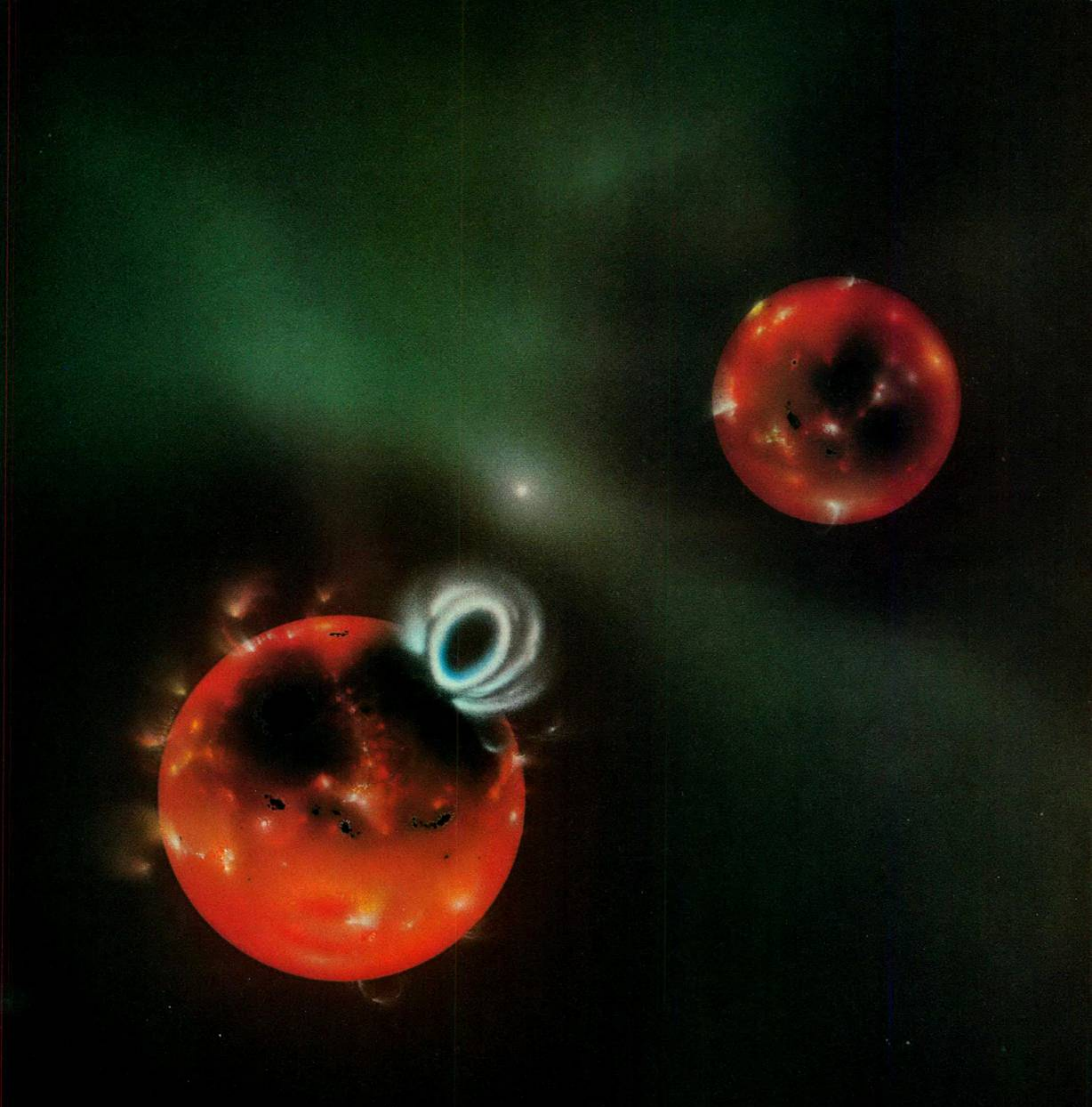
For the most part, these stars are truly inconspicuous. With such small masses, they are intrinsically faint. An M2 dwarf has an absolute magnitude of about +10 and an M4 one of +11.5 (Absolute magnitude is the magnitude a star would have if it were at a distance of 10 parsecs, or 32.6 light-years, from us. The absolute magnitude of the Sun is +4.4) Hence we see members of this class of stars only if they are nearby. By no means do they advertise their presence in the Galaxy.

However, we have our backs turned most of the time. There are instances when one of these stars will erupt spewing out in a minute — from a small spot on its surface — the energy which would normally have trickled out in an hour. The astronomer Willem J. Luyten reported such a flare of more than 2.5 magnitude on the star L726-8 (UV Ceti) on December 7, 1948. In his announcement in early 1949, he noted the similarity of this outburst to the events on the other dwarf M stars BD +44° 2051B and Ross 882



Painting by Anne Norcia

Numerous, small, and dim — many red dwarf stars are prone to frequent outbursts of violence. The graph shows the progress of a flare on the star DO Cephei over a period of thirteen minutes. Scientists are only beginning to understand the causes and significance of these outbursts.



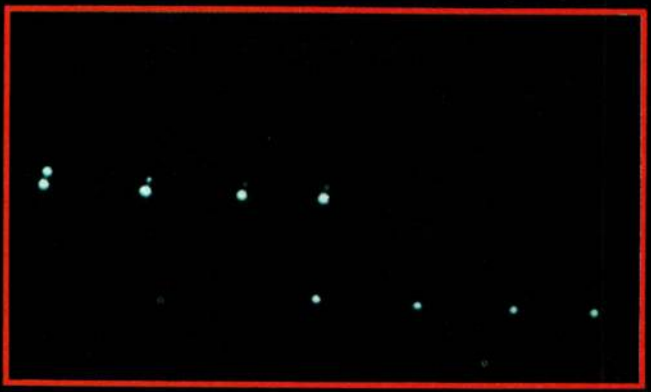


Photo courtesy of S.L. Lippincott and Sproul Observatory

The CM Draconis system, seen above in an artist's conception, is an eclipsing binary in which at least one component is a flare star. A loop of magnetic flux has detached itself from the star and is in the process of "collapsing." In addition to the eclipses of about 0.7 magnitude, there is a small variation of 0.01 magnitude in the interval between eclipses. The most probable cause for this tiny variability is the presence of starspots rotating with one of the stars. CM Draconis is also unusual because, while both components are approximately the same size — twice the diameter of Jupiter — each has 200 jovian masses, implying densities twice those normal for such stars. At left is a photograph taken by Armstrong Thomas in 1939 with the Sproul Observatory 24-inch refractor. It presents four successive images of the binary Kruger 60 A,B (with a distant optical companion C). The last exposure (far left) shows a fourfold increase in brightness of the fainter component.

Painting by Mark Paternostro

reported previously. Another similar event, again observed by Luyten, provided confirmation of UV Ceti's earlier flare, and prompted a search for other flares of UV Ceti on plates in the extensive Harvard collection. Harlow Shapley, reporting this work in 1949, listed brightenings dating back to 1900. Flares of other dwarf M (dM) stars were quickly reported as a result of both new observations and the re-examination of old plates. Currently there are more than 100 flare stars known.

The stars are characterized by short increases in brightness. They can range from as little as one magnitude to as many as six magnitudes. In a typical flare star, maximum brightness occurs within a few seconds after the flare begins, and the total duration is about 5 to 10 minutes. There's a striking similarity between the light curve of a "spike" flare and that of a nova or supernova, but about one-third of all flares are more gradual, with no prominent initial spike in luminosity.

There seems to be no evidence supporting regular recurrence of single flares, although the overall rate of flare occurrence in any one star may fluctuate over a period of years — in a way reminiscent of the 11-year solar cycle. While this suggests an intriguing connection, the observations are still too scant for any specific conclusion.

What are we seeing? And what is physically occurring on the star when it flares? In the first place, we "see" with different instruments and in different parts of the electromagnetic spectrum. The near ultraviolet region of the spectrum, observed with a suitable filter, usually reveals the most information about the brightness and its variations over time. The reason for choosing to look in this particular portion of the spectrum is based — strangely enough — on the fact that dM stars are particularly faint in this region. This is because dM stars, typically of small mass and low luminosity, are cool — their surface temperatures only about 3000° K. Such stars have their luminosity peaks in the red region of the spectrum. Very little (less than 10%) of the total radiation is emitted with wavelengths shorter than 5000 A (blue-green light), which is why these stars appear so red to our sight.

Whatever the actual physical mechanism that produces the flare, one fact is clear: The star releases a lot of energy in a short interval of time. Analysis of the characteristics of the first UV Ceti flare observed by Luyten indicated that at least 4×10^{31} ergs of excess energy were emitted. This is equivalent to about 4000 seconds of UV Ceti's normal radiation — but it emitted all of this energy in the space of a few minutes.

The process producing the eruption must be energetic, at least with respect to the "inactive" star. The increase in light intensity can be explained in either of two ways: by a general temperature rise of about 40° K or 50° K across the entire star, or by a smaller area rising to a much higher temperature. The latter alternative makes more sense physically. So we are dealing with a small area of the star, a hot spot, violently erupting and gushing out streams of radiation into space.

What characteristics should this radiation have? Since it was produced in a region of the star much hotter than the surrounding 3000° K surface, the peak in the spectrum of the radiation should correspond to the higher temperature of the region producing the blast. Depending on the size of the flare, this temperature can be tens of thousands of degrees. Consequently, the peak luminosity of the emitted radiation should fall not in the red, but in the ultraviolet.

Picture yourself monitoring this cool, faint, red star in the ultraviolet region of the spectrum, noting how much fainter it appears there than in the red. Suddenly, the star erupts! The flaring region sends forth a torrent of ultraviolet radiation streaming into your instruments. Your equipment records a dramatic increase in the brightness of the star. However, the hot spot does not produce much red light. So, if you were observing the star in the red region or even in the visible region of the spectrum, hardly any increase would be noted at all. The greatest change in luminosity would occur in the ultraviolet.

As data were being amassed on the frequency of these outbursts, the rate of flare occurrence was reported in 1961 as one per 30 to 50 hours of observation. But as more people began observing this type of star and more statistically meaningful samples were obtained, a range of one flare per 11 to 25 hours of observation was given in 1966. In 1975 DO Cephei produced 22 flares during 57.4 hours of actual observing time. The eruptions are really not at all infrequent.

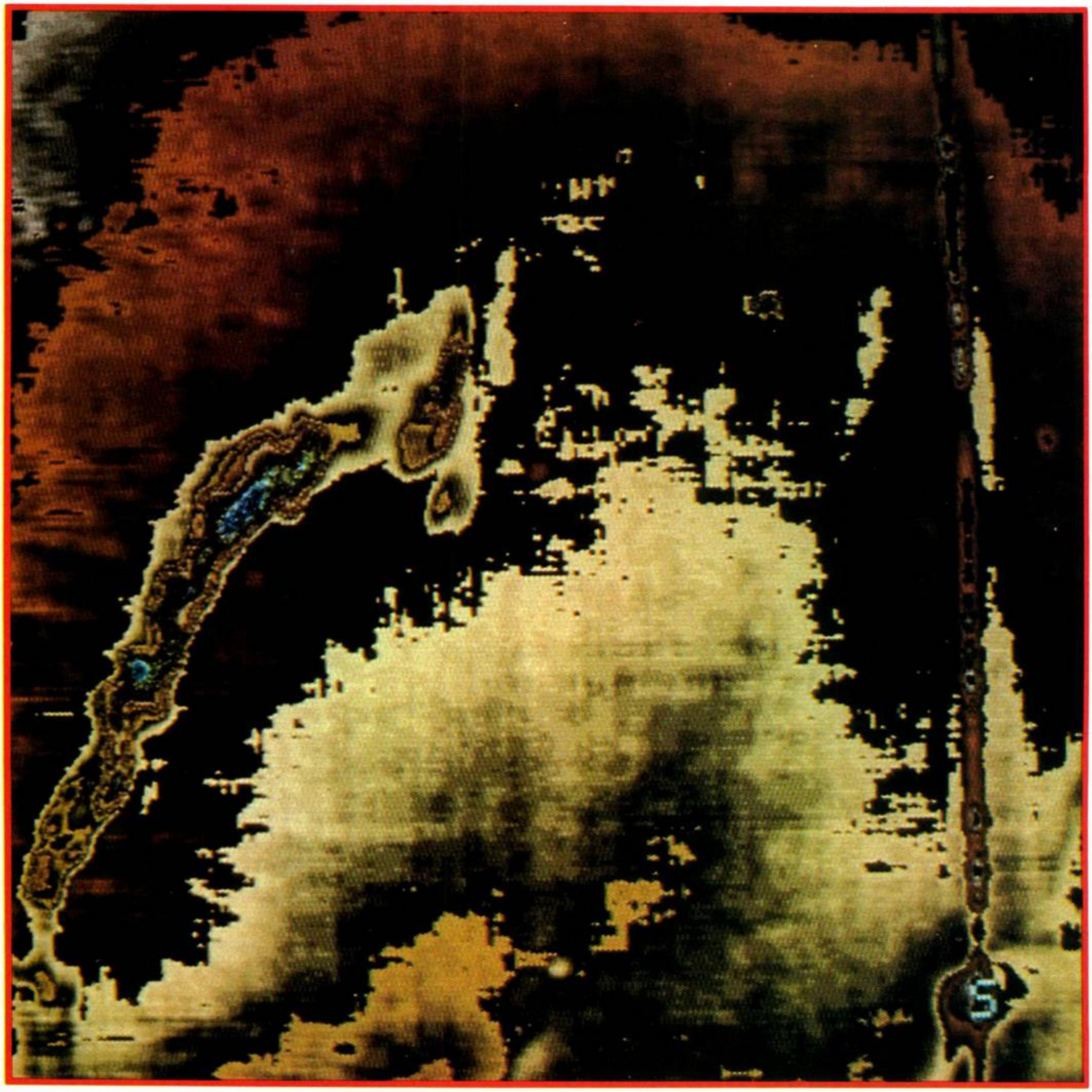
In attempting to understand the phenomenon of a stellar flare, we can draw an analogy between events on M dwarfs and similar occurrences on the Sun — solar flares. Unfortunately, we do not have a firm understanding of the mechanism which generates the energy and accelerates the particles in a solar flare (see "The Solar Maximum Mission," ASTRONOMY, May 1981). We know they are associated with the active regions on the Sun known as sunspots — areas of very intense magnetic fields. At the center of a sunspot, the field strength can be as high as 2000 gauss. Compare that to the strength at the poles of about 1 or 2 gauss and the Earth's surface field of one-half gauss. Because we know that "starspots" would be associated with strong magnetic fields, flares in stars like UV Ceti might be associated with some kind of starspots. Let's look for evidence.

Not all dM stars are flare stars. Those that have been observed to flare do show emission lines — generally of hydrogen — in their spectra. These are classed dMe, the "e" appended for "emission." This may be a case of observational selection — i.e., in the early days, when the first few flare stars had been discovered, researchers noted they were indeed emission line objects. So when Bidelman's list of cool emission line objects became available in 1954, observers searched through it for flare star candidates. Also, since the first few flare stars discovered were members of binary systems, in addition to looking for dMe stars, scientists searched out possible candidates for flare stars among dMe stars in binary systems. To some extent, then, far too many dMe stars in binary systems were found because those were the systems that were observed.

This may not be as obvious a case of bad statistics as it first appears. Scientists sometimes play out an intuitive guess, even though the physical theory backing this guess did not arrive until the mid-seventies. It was then that the observations of dMe stars indicated magnetic field strengths of at least 10,000 gauss, which seem to be a feature of dMe stars in general and flare stars in particular. Ordinary dM stars, that is, M dwarfs with no emission lines, do not have fields even remotely approaching this strength, and do not seem to flare. Just as in solar flares, stellar flares may be associated with active regions on a star with locally high magnetic fields.

But are these regions of intense magnetic fields associated with starspots? Calculations by D.J. Mullan of the Bartol Research Foundation suggest the answer is yes. One model of the flare star YY Gem indicates that the surface field of a spot can have a strength of 20,000 gauss, with the spot itself covering 50 to 60 degrees in longitude on the surface. In fact, small periodic variations in the brightness of the flare stars YY Gem, CC Eri, and BY Dra fit a picture of a large spot on the surface rotating with the star.

We must be careful in discussing the rotational period of a gaseous object like a star. In the case of the Sun, sunspots are our means of measuring rotation. But the Sun is not a solid body, and spots at different latitudes rotate at different rates. The mean rotational period of the Sun is 27 days. The rotational period of BY Dra as measured by starspots varied from 3.836 days in 1965-66 to 3.780 days in 1971. This change in period is analogous to the change in the rotational period of the Sun during a solar cycle. As



Although the largest solar flares are insignificant compared to the tremendous explosions of flare stars, astronomers believe there are many similarities. NASA Solar Maximum Mission photograph.

sunspots drift toward the equator in the later stages of the solar cycle, the rotational period as measured by the rotation of sunspots decreases. If a similar effect is responsible for the changes of period in BY Dra and holds true for all flare stars, then the drifting of the spots causes *latitudinal shear* — a faster rotation at the equator than at the north and south latitudes of the star. Astrophysical models predict this variation at the surface of the star would produce powerful dynamos, or flows of electric current, resulting in enormous magnetic fields at the starspot sites. This, coupled with the fact that red dwarfs as a class rotate much more rapidly than the Sun, further supports the dynamo mechanism model.

But what generates the energy that powers the flare? One theory is based on the fact that starspots are dark. One to two thousand degrees cooler than the surrounding photosphere, the umbra of the spot allows only the lower energy photons to pass through from the deeper layers. The spot therefore blocks the passage of higher energy radiation. If it is possible to store this energy in or under a spot, then a steady accumulation of even a fraction of the missing energy in starspots could indeed energize stellar flares. While this theory takes into account both the rate of flare occurrence and the average magnitude of the blasts in typical flare stars, unfortunately it fails, because scientists currently have no idea how this energy could be "stored." The lack of a mechanism casts a shadow on this explanation of stellar flares.

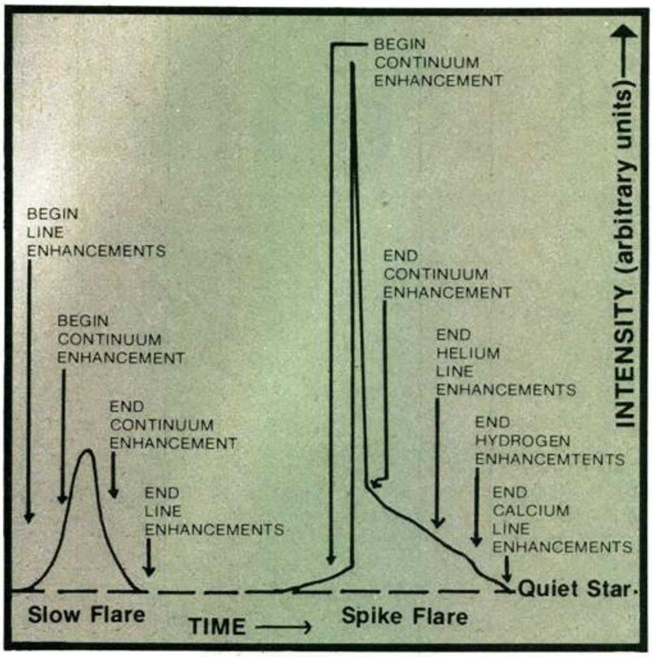
The magnetic storm theory puts forth another hypothesis — that the basic mechanism of flare activity is the conversion of the energy of the intense magnetic fields into photon energy by a collapse phenomenon which pumps energy into a very restricted volume of space. The transfer of energy from the magnetic field must take place at a very rapid rate, and it must also be converted into photon energy very rapidly. Presumably, in both cases the rates are greater than are possible by conduction or ordinary convection. Astrophysicists theorize that the driving force of a stellar flare is the detachment and subsequent collapse of a loop of magnetic flux, which forms a constricting torus like a shrinking doughnut. During this cataclysmic collapse, the fields polarize the plasma composed of ionized, charged atoms in the small volume. This process stores energy in the volume. As collapse occurs, the magnetic field disappears and the volume becomes the seat of violent *collisional recombinations* between free electrons and ionized atoms, which result in the emission of photons by the "captured" electrons. Recombinations (which occur rapidly) give rise to the radiation characteristic of the spike phase of the flare. The relatively slow cooling phases are characterized by downward transitions to lower energy levels of recombined hydrogen and other atoms, the expansion of the flare volume, diffusion and conduction, and a succession of emission line maxima corresponding to a succession of decreasing temperatures.

We can account for the slow flares, which do not show the characteristic initial "spike," by invoking weak magnetic structures in which the collisional energy is not sufficient to cause hydrogen recombinations. They do, however, show the cooling phases.

Returning to solar flares for further clues about flare stars, we notice two outstanding properties. First, flares on the Sun are responsible for producing high energy particles and, consequently, a component of mass loss contributing 10 to 15 percent of the total mass loss in the solar wind. Second, due to the energetic nuclei accelerated in certain solar flares, such events may be the sites of nuclear reactions. Since flares on red dwarfs can be more energetic than solar flares, this may have significant effects on the interstellar medium and the whole galactic environment.

What are the consequences of mass loss due to stellar flares? Our Galaxy has a total mass of 1.4×10^{11} Suns (abbreviated $M_{\odot}$). This includes contributions from all stars, white dwarfs, gas, dust, and "missing mass." (There may be even more missing mass, though; see "The Invisible Universe," ASTRONOMY, May 1981.) About 80% of that total — believe it or not! —is contained in M dwarfs. A 1979 survey of the spectral types of M dwarfs by Joy and Helmut Abt shows that roughly half of the dM2.5 to dM5 stars have emission lines, while all later type dwarfs are dMe. Applying these results, there are about 5×10^{11} (500 trillion) dMe stars in our Galaxy. (Remember, it's the emission line dwarfs — dMe types — which are flare stars.) Thus, with so many M dwarfs, even low rates of mass loss can be significant in determining the mass and energy balance of the interstellar medium. The best estimate for the rate of mass loss for flare stars is 2×10^{-13} solar masses per year per star from the flare events themselves. This does not include the contributions of a stellar wind, which raise the rate to about 1.2×10^{-12} $M_{\odot}$/yr/star. Multiplying the number of dwarf stars in the Galaxy (5×10^{11}) by 1.2×10^{-12} $M_{\odot}$ (the annual mass loss per dwarf star) gives us 0.6 $M_{\odot}$. If, indeed, flare stars inject 0.6 solar masses of material per year into the Galaxy, they are the dominant depositor of matter into the interstellar medium. They would contribute four times as much mass as each of the next three highest sources (MII giants, OB stars, and the explosions producing planetary nebulae), and probably more than all other sources combined.

Flare stars also appear to be an important source of energy for the interstellar medium. Energy from the blast waves of flares add about 5×10^{48} ergs per year to the interstellar medium. The amount of energy from supernovae is about 1×10^{49} ergs per year, assuming supernovae occur at a rate of one every hundred years in our Galaxy. Roughly equivalent amounts of energy are produced by the interaction of cosmic rays with the interstellar gas. Thus the energy input of dMe stars is certainly significant — and may be nearly as great as other energy sources.



Slow flares have relatively gentle rises to maximum, with emission lines dominating the spectrum. Spike flares, on the other hand, increase rapidly in brightness to a sharp maximum and decay almost as quickly. Radiation from the flare occurs over a broad range of wavelengths during the spike portion, and specific emission lines appear only where the spike ends and the gradual decline to the quiescent level begins.

Although mass loss from flare stars is probably a significant contributor to the mass of the interstellar medium in our Galaxy, it may not be true that it is responsible for the majority of the mass simply because there is already a lot of interstellar material in our Galaxy. On the other hand, in galaxies with little or no present interstellar medium — such as elliptical galaxies — mass loss from flare stars may be more important. After the ejected material from a flare has come to thermal equilibrium, the mean proton velocity is about 600 km/sec, greater than the escape velocity for a 10^{11} $M_{\odot}$ elliptical galaxy. The particle escape time would be short — about ten million years. Thus, gas would escape from such galaxies as a "galactic wind," even in the absence of supernovae. This mass loss mechanism would keep elliptical galaxies free from a substantial gas component — fitting our observations.

So we see that the little fits of temper displayed by those diminutive flare stars may well have a profound effect on the galactic environment. And stellar flares can shed light on the mechanics of flares on the Sun. Relative to solar flares, red dwarf flares have the advantage that optical radiation from the hot flare plasma is easier to detect because the flare is viewed against the background of a cooler photosphere. Today, however, some of the physics is still unclear. Perhaps by turning a steady eye toward the heavens, the answers may come. But if we turn our gaze toward some small red star, we may see it shoot out an angry fist at us for disturbing its quiet!

Anthony J. Nicastro is a research fellow of the Bartol Research Foundation at the University of Delaware. He has worked on model atmospheres for cool white dwarfs and has done observational work on flare stars. His Ph.D. is in condensed matter physics.

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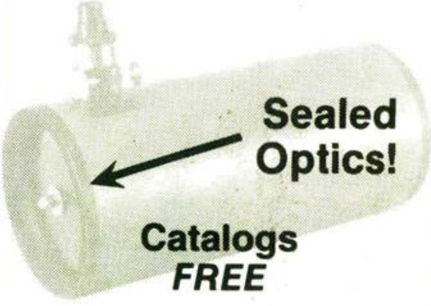

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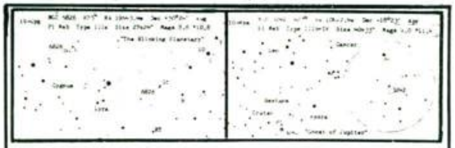

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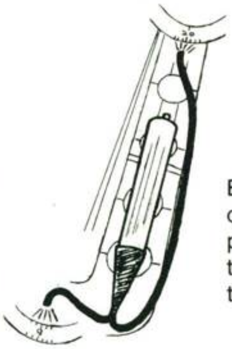

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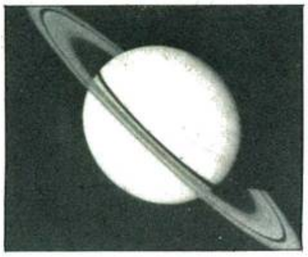

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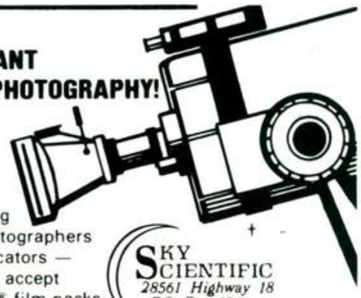

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ANNOUNCEMENT — Springfield Mass. Stars Club meets the 4th Wednesday of every month at 8:00 p.m., Sept. through May, at the Museum of Science, 231 State St., Springfield, Mass. Contact John Welch, 107 Lower Beverly Hills, West Springfield, MA 01089. Phone (413) 734-9179.

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WANTED — *Physical Characteristics of Comets* by S.K. Vsekhsvyatskii. Translated from Russian, 1964 edition. State condition and price. Contact C. E. Spratt, 1431 St. Patrick St., Victoria, B.C., V8S 4Y5 Canada.

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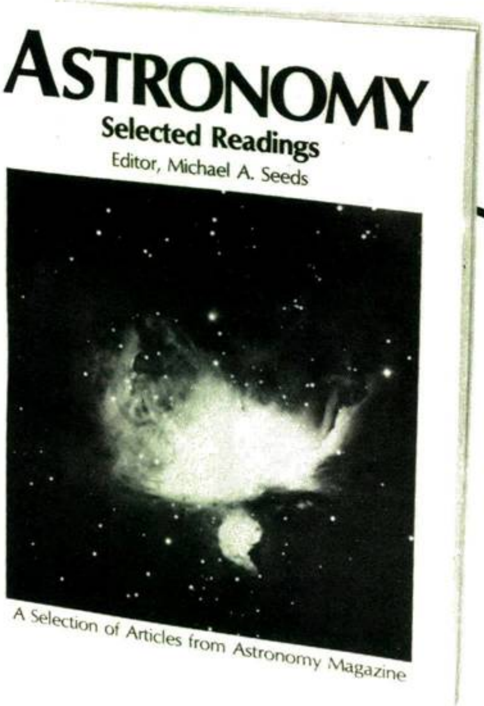

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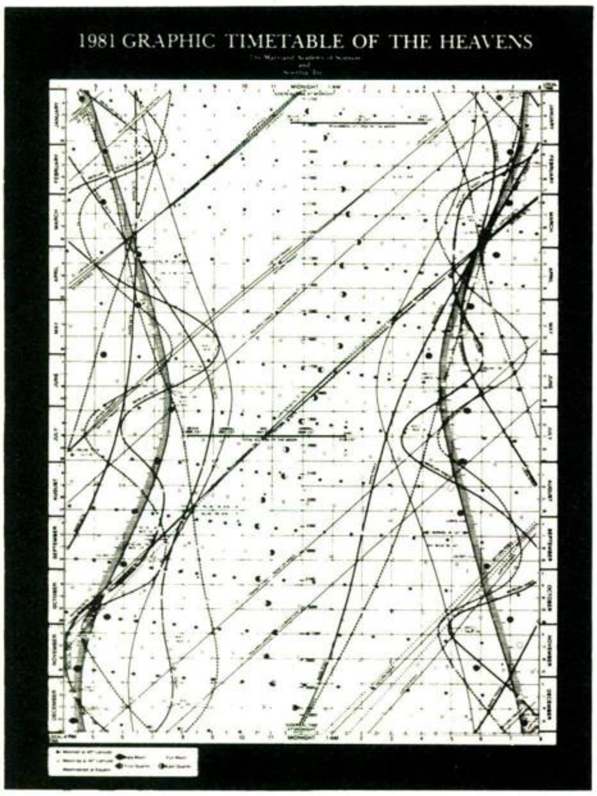

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close-up on virgo

through the eyepiece

June offers the planet-watcher beginnings and ends: Mercury finishes an evening apparition, Venus starts one. Mars emerges from the Sun into the morning sky, and Jupiter and Saturn, past the meridian at sunset, have begun their decline toward the oncoming Sun. Other events: Uranus has two close conjunctions with stars, and Neptune is at opposition.

Mercury

Mercury will be visible in the western sky after sunset for about the first week to ten days of June. After that, you'll probably find it is too close to the Sun to be visible, but just to test yourself, see how late in the month you can follow it. (See the May issue for a diagram of its motions.) On the 22nd, Mercury passes through inferior conjunction, shifting from the evening sky to the morning.

With a telescope, you can see crescent Mercury shrink from 26% lit on the 1st to 9% lit on the 11th. At the same time, it will grow slightly in apparent diameter, from 9.1" of arc to 11.1".

On the evening of June 3rd, about 4° to the lower left of Mercury, you'll see the Moon, 1.5 days old and only 3% lit. (At the same time, look for Venus about 5° to the lower right of Mercury, making a nearly equilateral triangle with the pair.)

Venus

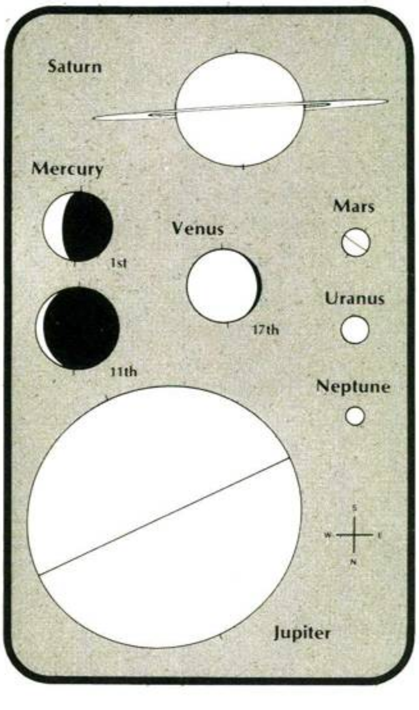
Venus' apparition in the evening sky during the rest of this year won't be anywhere as striking as the last. As the diagram on page 84 shows, its path will be a long, low arc essentially parallel to the horizon until late summer/early fall. Then it will climb substantially higher for a short time before it plunges down toward inferior conjunction with the Sun on January 21, 1982.

"Best Astro-Photo" for June is Orien Ernest's spectacular photograph of M-42, the Orion Nebula, and its small companion to the south, NGC-1977. Ernest used a 15-minute exposure on Ektachrome 400 with a dry ice cold camera at the prime focus of his 8-inch f/5 Newtonian telescope.

In a telescope's eyepiece this month, the slightly non-circular disk of Venus will appear only about 10.5" of arc in diameter — not very large.

Earth

The summer solstice comes on June 21 at 11:45 UT, when the Sun will halt its northward drift and begin moving southward on the celestial sphere. Then, after 183 days 11 hours and 6 minutes (at 22:51 UT on December 21), it will reach its southern limit and mark the winter solstice.



Mars

Mars won't appear in the morning sky until about the middle of June, and even by the end of the month, it will be only 7° high in the east-northeast, 45 minutes before sunrise. On the morning of the 30th, the Moon (a day and a half before New) will lie about 4° below Mars. Sharp eyes, a low and unobstructed horizon, and some luck may permit you to find Mercury there also (about 3° below the Moon). But since the planet will rise only 30 minutes ahead of the Sun, the sky will be very bright.

Asteroids

1 Ceres (magnitude 8.3) lies in central Cancer at the start of June and moves into eastern Leo by the end. It will pass 4′ of arc north of Lambda (λ) Leonis on June 29th. Its positions:

10th: 8h 57m 41s, +25° 40.9′
20th: 9h 14m 34s, +24° 25.6′

Ceres sets around midnight local daylight time on June 15.

2 Pallas (8.9) is in conjunction with the Sun on July 21 and will lie too close to the Sun to be seen this month.

3 Juno (10.7) spends the whole of June in eastern Virgo. Its positions:

10th: 13h 29m 27s, +2° 32.2′
20th: 13h 38m 58s, +2° 16.4′

Juno sets around 2:30 a.m. local daylight time at mid-month.

4 Vesta (7.7) lies in Leo to the southeast of Algieba (Gamma [γ] Leonis). Its positions:

10th: 10h 47m 3s, +15° 24.0′
20th: 11h 00m 6s, +13° 46.5′

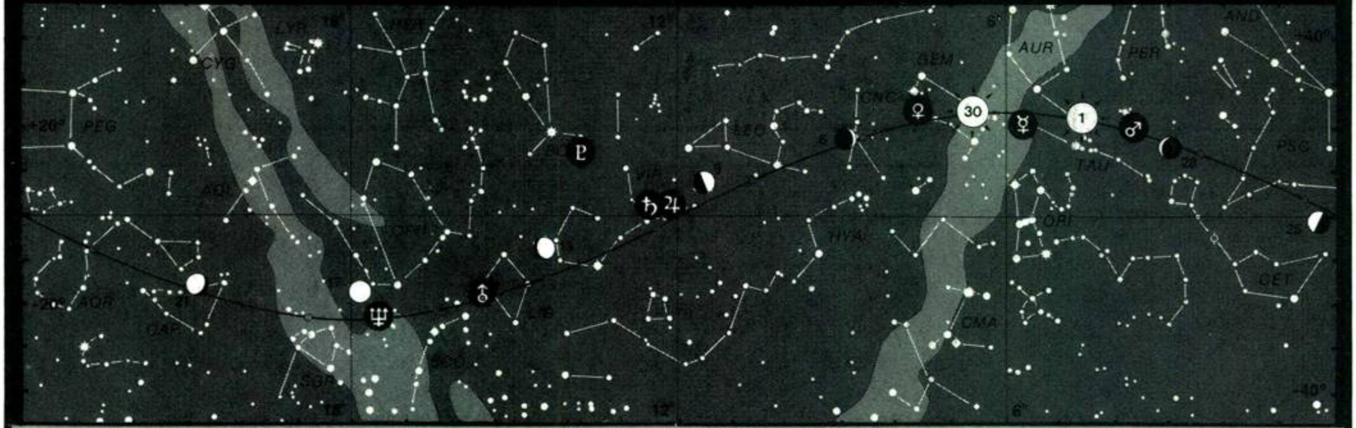
Vesta sets around 1 a.m. local daylight time on June 15.

Jupiter

Jupiter-watchers may have noticed that the planet's oval ball is becoming slightly lopsided: the eastern side appears less pronouncedly oval than the western. What's happening?

On June 23, Jupiter will be 90° away from the Sun in the sky. Technically called *quadrature*, this 90° elongation means we can look slightly "behind" Jupiter's sunrise terminator onto the planet's night-side. The resulting visual effect — which many observers have noted to be more apparent in a twilight sky than in full darkness — is

planetary data june 1981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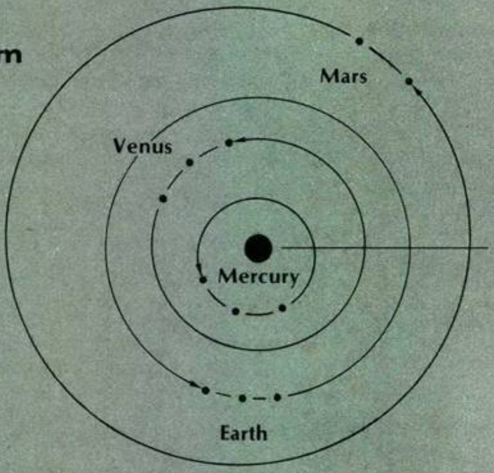
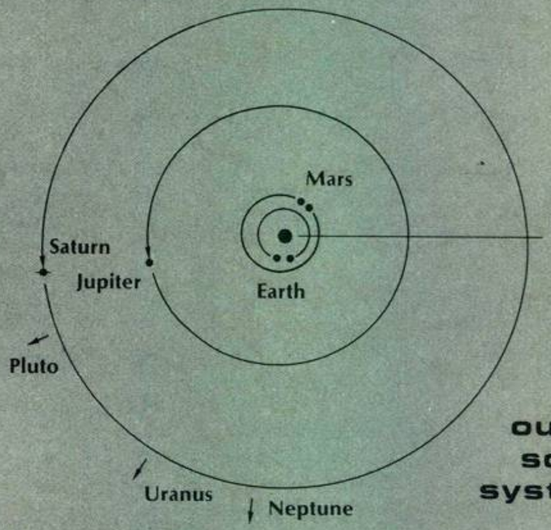
+40°
+20°
-20°
-40°
30
1

inner solar system


Mars
Venus
Mercury
Earth


Mars
Saturn
Jupiter
Earth
Pluto
Uranus
Neptune

outer solar system

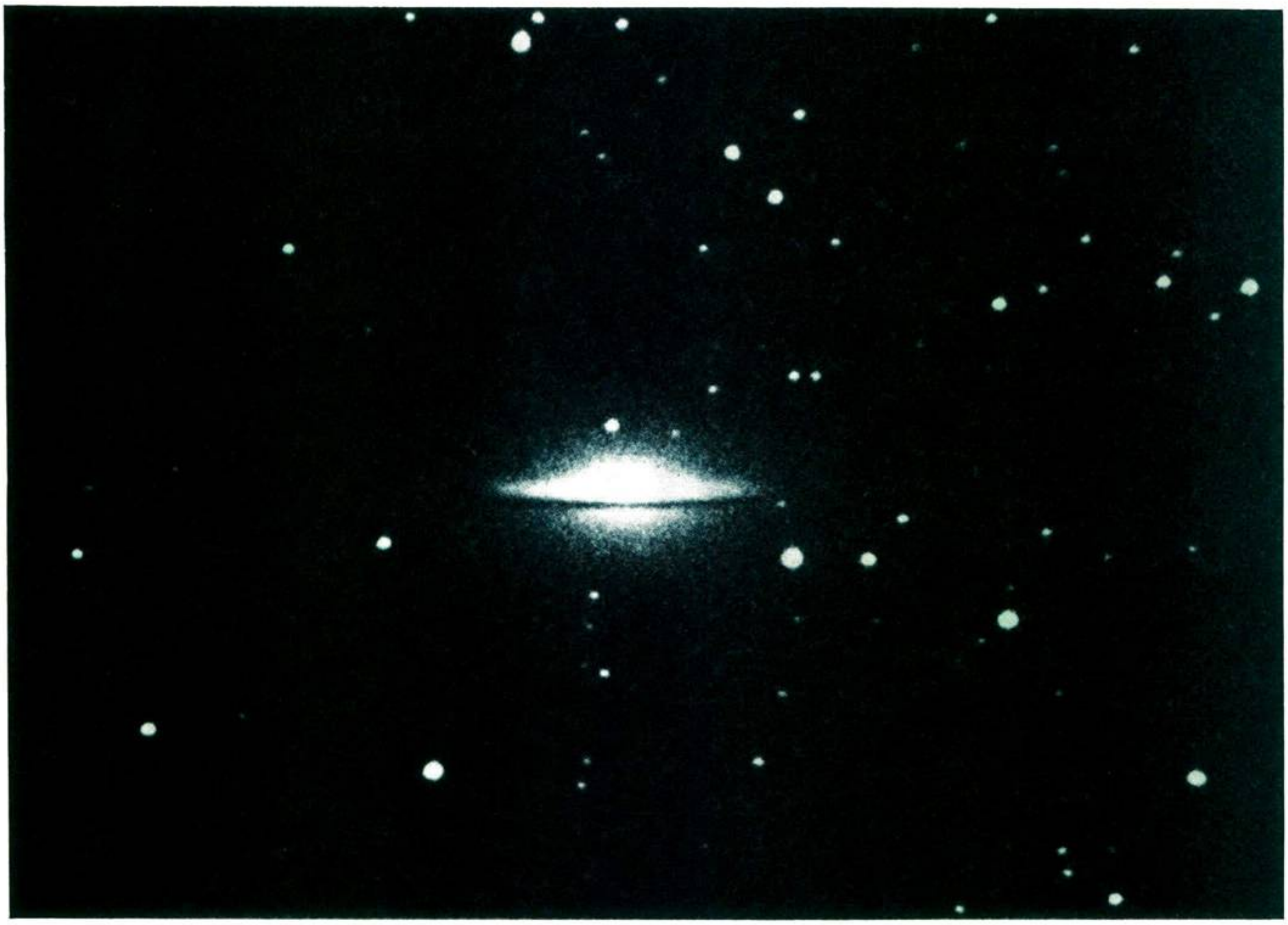
				Angular	%	Distance (AU) from:		Longitude:			
		Date	Mag.	Size	Illum.	Earth	Sun	Heliocentric	Ecliptic	R.A. (1981.5)	Dec
Sun		1	-26.7	31.6′	—	1.01	—	—	70°25.4′	4h 35.2m	+22°00.6′
		15	-26.7	31.5′	—	1.02	—	—	83°49.0′	5h 33.0m	+23°17.7′
		30	-26.7	31.5′	—	1.02	—	—	98°07.6′	6h 35.3m	+23°11.5′
Mercury	☿	1	+1.1	9.1″	27%	0.74	0.43	210°24.3′	91°53.9′	6h 10.9m	+24°40.1′
		15	+2.5	11.7″	4%	0.57	0.47	251°08.0′	93°41.4′	6h 17.7m	+21°08.0′
		30	+2.3	11.0″	5%	0.61	0.44	293°40.5′	86°22.8′	5h 46.6m	+18°43.6′
Venus	♀	10	-3.3	10.3″	96%	1.63	0.72	119°52.3′	95°21.5′	6h 25.4m	+24°20.5′
		30	-3.3	10.9″	92%	1.55	0.72	152°22.4′	119°45.4′	8h 10.9m	+21°36.1′
Mars	♂	15	+1.7	3.9″	99%	2.43	1.49	55°30.9′	66°36.9′	4h 20.4m	+21°35.3′
Jupiter	♃	15	-1.7	37.6″	99%	5.23	5.45	191°35.9′	180°30.4′	12h 05.6m	+0°52.5′
Saturn	♄	15	+1.1	17.8″	100%	9.36	9.58	189°05.7′	182°38.6′	12h 15.2m	+1°02.2′
Uranus	⛢	15	+5.8	3.8″	100%	17.91	18.82	238°26.0′	236°40.8′	15h 39.2m	-19°17.1′
Neptune	♆	15	+7.7	2.5″	100%	29.26	30.28	263°29.2′	263°02.8′	17h 31.9m	-21°55.0′
Pluto	♇	15	+14.0	—	100%	29.57	30.04	203°24.5′	201°15.4′	13h 45.8m	+7°43.1′

moon data

New Moon	June 2 at 11:32
First Quarter	June 9 at 11:33
Full Moon	June 17 at 15:04
Last Quarter	June 25 at 04:25
New Moon	July 1 at 19:03
Perigee: June 1 at 14h	358,483 km
Apogee: June 14 at 3h	405,798 km
Perigee: June 29 at 19h	362,350 km

universal time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times given in Through the Eyepiece are UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then EDT for the event is 11 p.m., June 6. Likewise, 03:00 UT on September 2 becomes, in PDT, 8 p.m., September 1.



Seen nearly edge-on, the Sombrero Galaxy (M-104) in Virgo clearly shows its dark dust lane. Among the brightest of the Virgo cluster members, M-104 is also one of the most massive galaxies known. Photo by Lee Coombs on 103a-O, using a 10-inch f/5 scope at prime focus and a 15-minute exposure.

an imperfectly oval disk.

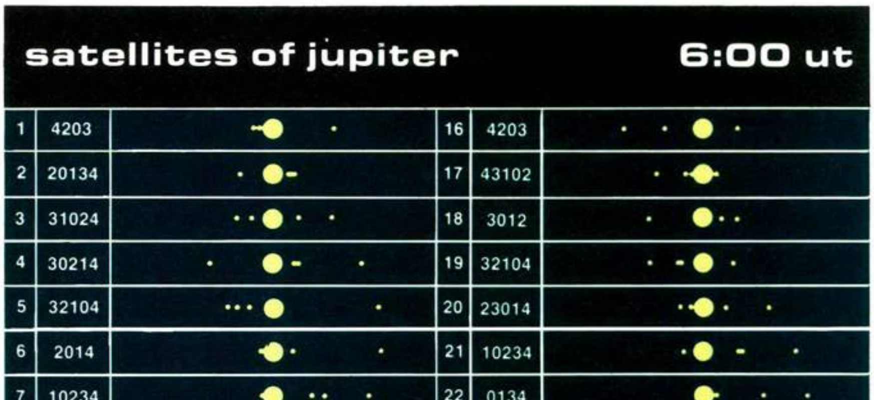
Saturn

Saturn, too, shows a very slight phase at quadrature (which comes on June 25). But since the planet lies at a much greater distance from us and the Sun, the effect is barely noticeable.

June 1 marks the date when the ring system, which has been slowly tilting more and more edge-on to our line of sight, reaches its minimum of 4° 11′ and begins to open up again. If you observe with a small telescope, look for Cassini's Division. And if you can't see it now, keep trying in the weeks ahead to see how soon you can.

Uranus

For the first week of June, Uranus will lie about 15′ of arc north of 4.7 magnitude Kappa (κ) Librae. (It is 14′ of arc due north on the 4th.) Kappa is about 4½° southwest of 4th magnitude Theta (θ) Librae, a star shown on the Star Dome.



satellites of jupiter 6:00 ut

1	4203	16	4203
2	20134	17	43102
3	31024	18	3012
4	30214	19	32104
5	32104	20	23014
6	2014	21	10234
7	10234	22	0134
8	034	23	2034
9	20134	24	304
10	3102	25	30124
11	34012	26	32104
12	43210	27	23401
13	4201	28	41023
14	41023	29	40213
15	403	30	42103

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)

Uranus will have an even closer conjunction with another star, 41 Librae (5.5 magnitude), on the night of June 24/25. At 00:15 UT on the 25th, it will pass only 1′ 43″ north of the star.

Viewed in a telescope with moderate powers, Uranus' small grey-green disk is easily recognizable.

Neptune

At opposition on June 14, Neptune's 7.7 magnitude disk will be just 2.5″ of arc across. Retrograding about 1.5′ of arc per day, Neptune lies in southern Ophiuchus 4° to the northeast of the 3.3 magnitude star, Theta (*θ*) Ophiuchi.

close-up on virgo

Giant Virgo, the second largest of the constellations, sprawls across the sky high in the south this month inviting telescopic observers to examine her in detail. While the stars comprising this celestial figure are not on the whole particularly bright, there certainly is a lot to see here!

Most famous of Virgo's wonders are her galaxies, strewn mostly along her northwestern border and spilling over into neighboring Coma Berenices. These are members of the well-known Virgo cluster of galaxies, the nearest large cluster to our own Milky Way Galaxy. We'll look at them first and then sample some of the other treasures Virgo has to offer.

M-84 and **M-86** constitute a bright pair of elliptical galaxies found near the center of the cluster. Less than 20 minutes of arc apart, both can be included in the field of view of a low-power eyepiece. Although Messier wrote that "both have the same appearance," M-86 is slightly oval in comparison to the more spherical M-84. If you have trouble detecting this difference, note that M-84 lies farther west. And if you're still confused, turn off your drive — M-84 is the one leading the march across your field of view!

The giant elliptical galaxy **M-87** is in fact the center of this huge cluster, the hub around which all the others revolve. Look for a fuzzy ninth magnitude blob about 3′ in diameter, and remember that you are looking at the combined light of perhaps half a trillion stars. A strong source of radio emission, and therefore also known as Virgo A, M-87 is famous for the peculiar jet extending from its center — a sign of energetic activity which is still not clearly understood. But don't expect to see the jet — it only shows up on long exposure photographs taken with large instruments.

Above: Brian Tkachyk used Ektachrome 400 (pushed to 800 ASA), a 200 mm lens, and a 60-minute exposure for this photo of NGC-7000, the North America Nebula. Right: The southern highlands of the Moon were captured at First Quarter by photographer Steve Reed with his 8-inch telescope and eyepiece projection.

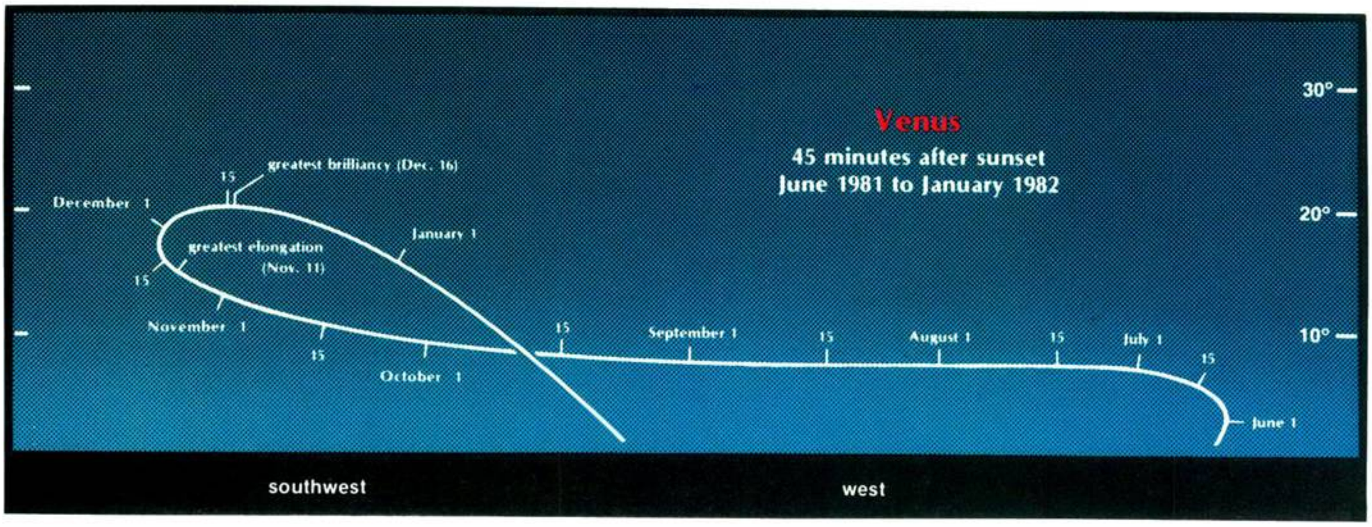
Swing your telescope somewhat more than a degree to the east and a little north of M-87, and you'll find another elliptical galaxy — **M-89**. Similar in appearance, M-89 is both smaller and fainter than M-87.

One degree north and a little to the east of M-89 brings us to **M-90** — this time a spiral galaxy. Noticeably elongated, M-90 is tilted significantly to our line of view and displays a bright star-like nucleus admired by many observers.

You'll find still another type of galaxy in this region. **M-58** is a ninth magnitude barred spiral somewhat inclined to our line of view. Those with larger instruments may be able to identify the bar as an east-west elongation of the nucleus.

M-59 and **M-60** form another "galactic double," separated by only half a degree, or about the diameter of the Full Moon. Both elliptical galaxies, M-59 is definitely the fainter of the two, and more elongated than the nearly circular M-60.

Farther to the south and slightly west



Venus
45 minutes after sunset
June 1981 to January 1982

of the grouping of galaxies described above, is the large face-on spiral **M-61**. The bright, almost stellar core is visible in any instrument, but with a large aperture the spiral structure stands out clearly.

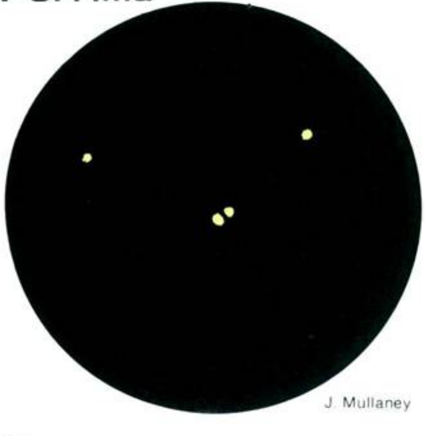
The brightest galaxy in Virgo is the slightly oval elliptical galaxy **M-49**. Located about halfway between M-61 and the others, M-49 is in fact one of the largest of all elliptical galaxies, with a mass five times that of our own spiral galaxy. T.W. Webb noted its "beautiful position" between two sixth magnitude stars.

Far down near the border with Corvus is **M-104**, famed as the "Sombrero Galaxy." M-104 is thought to be a tightly wound spiral, but the exact classification is difficult to determine because its orientation is only about 6° from edge-on. Its nickname derives from the dark lane of obscuring dust along the plane of the disk and the large, bulging central mass. The dust lane is difficult to detect in instruments of eight inches or less aperture, but the oval glow is bright and easy to see in any telescope. The hardest thing about M-104 may be finding it in the first place! Try starting from the star Gamma (γ) Virginis, swing ten degrees south in declination and just a little to the west in right ascension. A number of seventh magnitude stars in the same field enhance the view.

M-61

J. Newton

Porrima



J. Mullaney

Rounding out our survey of Virgo's galaxies is the pleasing spiral **NGC-4699**. A relatively bright ninth magnitude oval blur measuring about 2′ by 3′, NGC-4699 can be found about five degrees northeast of M-104.

Turning now to the multiple stars in Virgo, we first center **Gamma** (γ) **Virginis** (also known as **Porrima**) again in our eyepiece. An identical pair of 3.6 magnitude F-type stars separated by 4″ in position angle 300°, Porrima is regarded as one of the finest double stars in the sky. The color of each sun is white with a tinge of yellow. Although lacking the vivid color contrast of many doubles, this pair's intensely matched images have an appeal all their own. Only 32 light-years distant, the system has an orbital period of just 172 years. During this time, the distance between the two stars ranges from a minimum of 3 Astronomical Units to a maximum of 70. Closest approach (known as *periastron*) next occurs in 2008, so the separation is currently declining.

M-49

J. Newton

84 Virginis consists of a sixth magnitude primary accompanied by an 8.6 magnitude secondary just three arc-seconds distant (in position angle 229°). Both suns appear yellow-white in the eyepiece, with spectral types of K2 (primary) and G5.

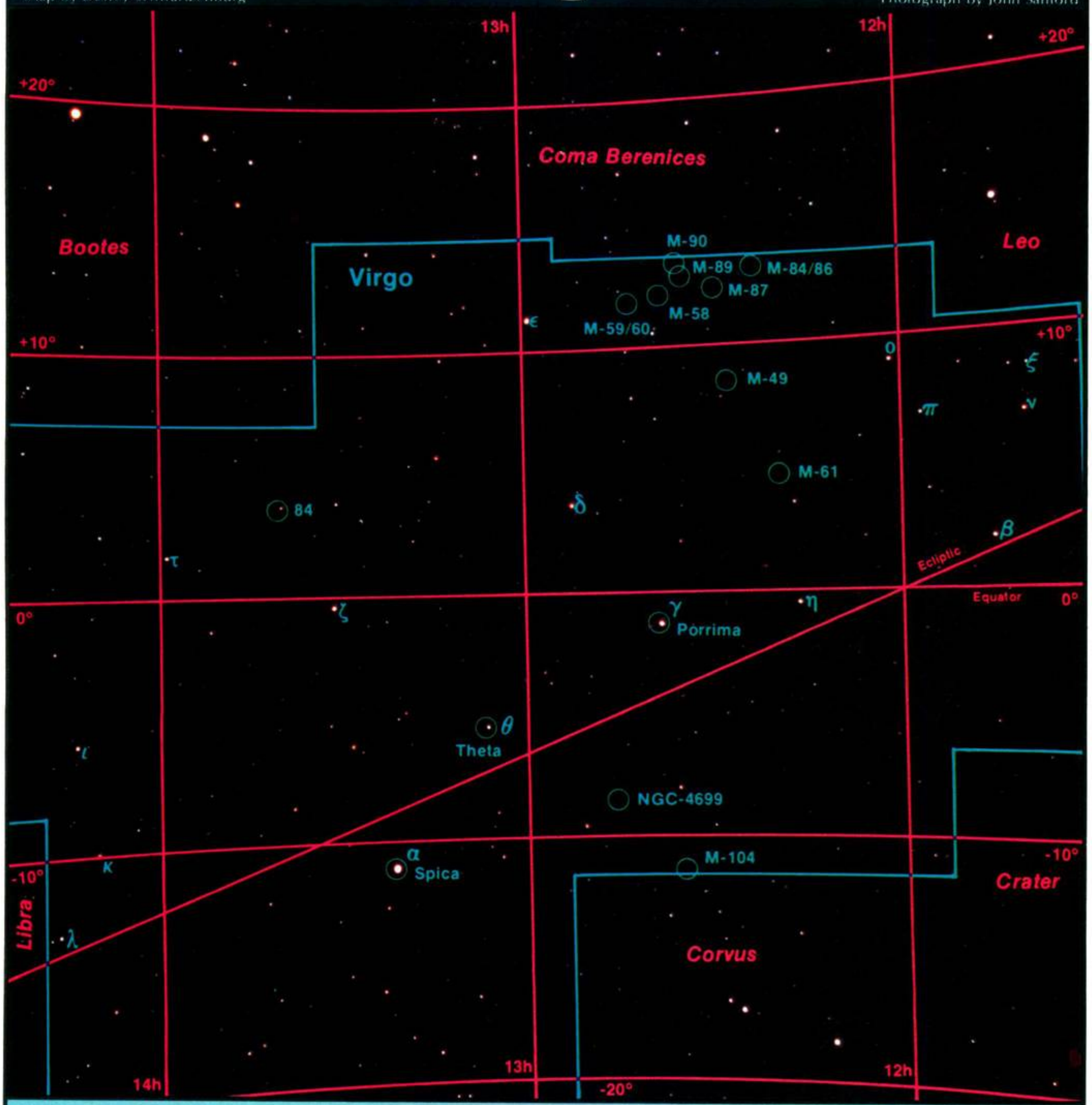
The triple system of **Theta** (θ) **Virginis** includes a close pair of stars with magnitudes of 4.4 and 8.6 separated by 7″ attended by a third tenth magnitude sun 71″ distant. It is not known if the members of this apparent triple are in fact physically associated.

Located in an otherwise dim region of the sky, **Spica**, the brightest star in Virgo, stands out clearly in the southern sky. Most observers see a definite tinge of blue in this first magnitude star's light, which agrees well with its spectral class of B1. Aside from its lovely color, Spica is also an eclipsing spectroscopic binary with a period of four days. Although both components are similar in size and luminosity, the eclipses are grazing ones resulting in a drop in brightness of less than a tenth of a magnitude. At a distance of 220 light-years, this rapidly revolving pair is too close to resolve visually in any telescope. If, however, we could view this system from a planet circling the pair, we would behold a blazing duo of hot, blue-white suns striding across the alien sky and separated by only about five million miles — less than their own diameters.

virgo

Map by Dewey Schwartzenburg

Photograph by John Sanford


13h
12h
+20°
+20°
Coma Berenices
Bootes
Leo
Virgo
M-90
M-89
M-84/86
M-87
M-58
M-59/60
ε
+10°
+10°
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ξ
π
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M-49
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84
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Spica
M-104
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Libra
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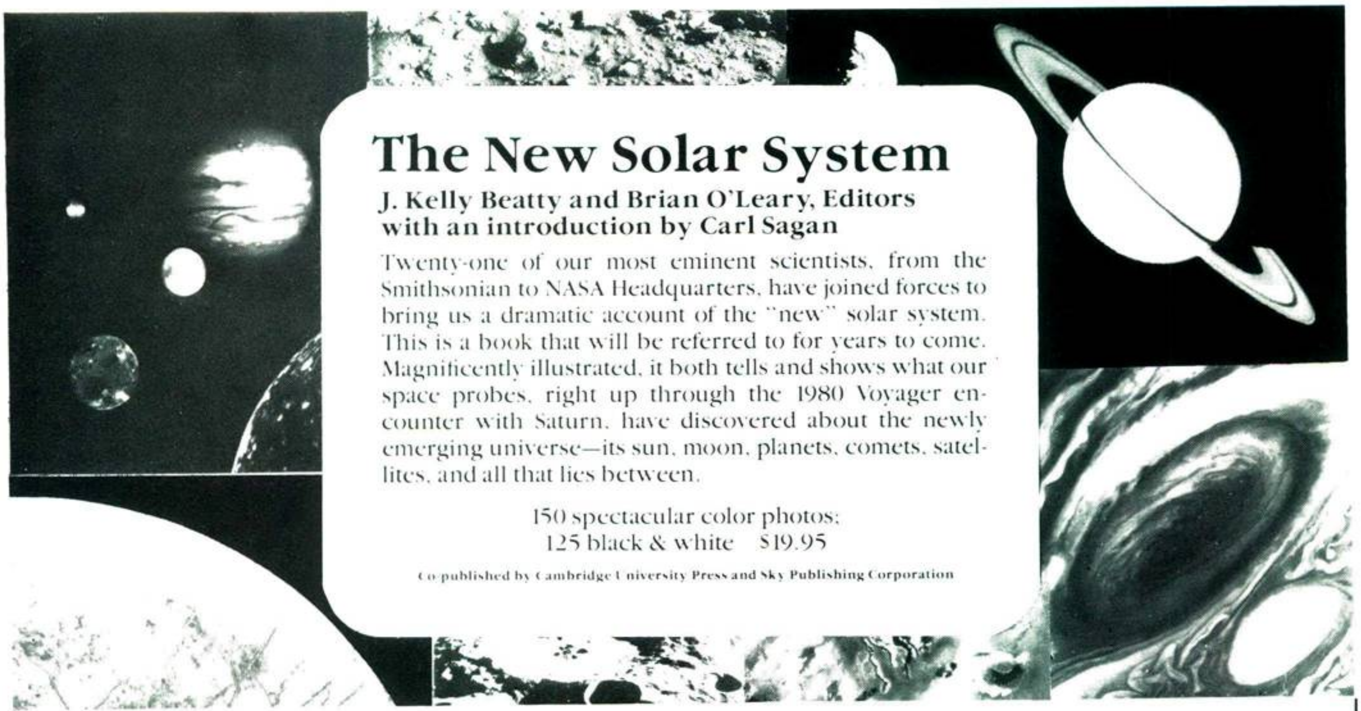
Corvus
14h
13h
12h
-20°

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (1981)	Dec.
M-61	§S	10.1	6′ x 5′	12h19m	+04°45′	12h21m	+04°35′
M-84/M-86	§0/§0	9.3/9.7	1.5′/2′x1.5′	12 23	+13°11′	12 25	+13°01′
M-49	§0	8.6	3′ x 2′	12 27	+08°16′	12 29	+08°06′
M-87	§0	9.2	2′	12 28	+12°40′	12 30	+12°30′
M-89	§0	9.5	1.3′	12 33	+12°50′	12 35	+12°40′
M-90	§S	10.0	7.5′ x 2′	12 34	+13°26′	12 36	+13°16′
M-58	§ʃ	9.2	4.5′ x 3.5′	12 35	+12°05′	12 37	+11°55′
M-104	§S	8.7	6′ x 2′	12 37	-11°21′	12 39	-11°31′
Gamma (γ)	★^{2}	3.6,3.6	4″	12 39	-01°11′	12 41	-01°21′
M-59/M-60	§0/§0	9.6/8.9	3′ x 2′/2′	12 40	+11°52′	12 42	+11°42′
NGC-4699	§S	9.3	3′ x 2′	12 46	-08°24′	12 48	-08°34′
Theta (τ)	★^{3}	4.4,8.6,10	7″, 71″	13 07	-05°16′	13 09	-05°26′
Spica (α)	★	1.2	-----	13 23	-10°54′	13 24	-11°04′
84	★^{2}	5.7,8.6	3″	13 40	+03°47′	13 42	+03°38′

★	*Star*
★^{2}	*Double Star*
★^{3}	*Triple Star*
ᗰ★	*Regular Variable*
∩★	*Irregular Variable*
ӾӾ★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
§S	*Spiral Galaxy*
§ʃ	*Barred Spiral Galaxy*
§#	*Peculiar/Irregular Galaxy*



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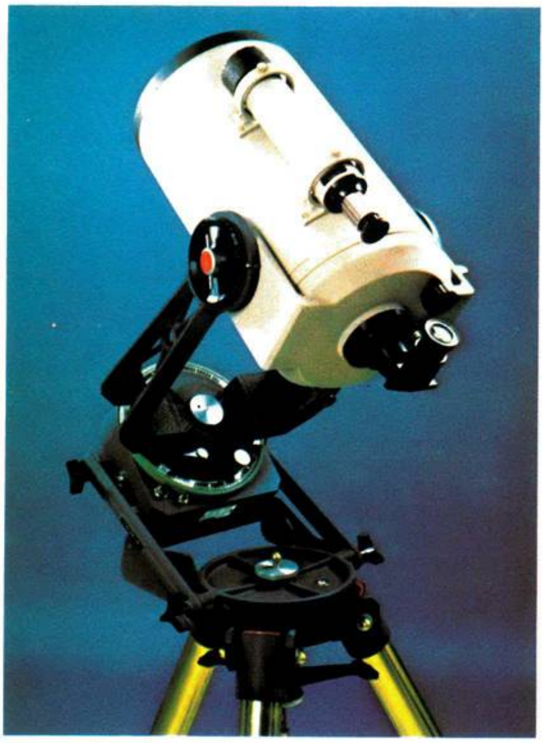

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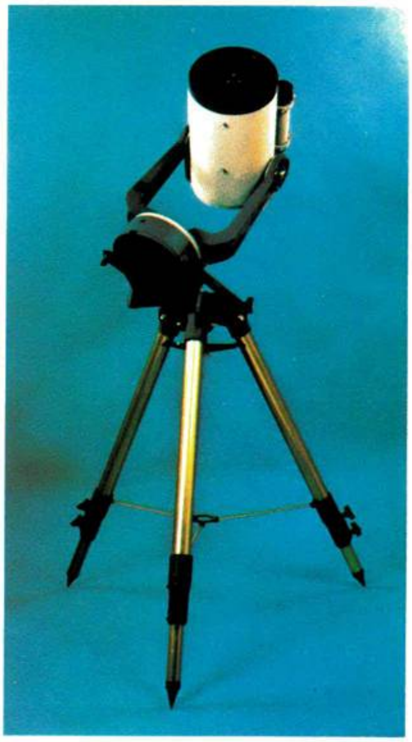

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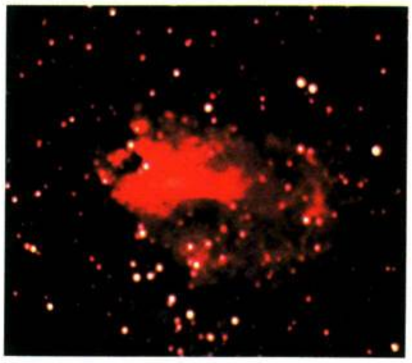

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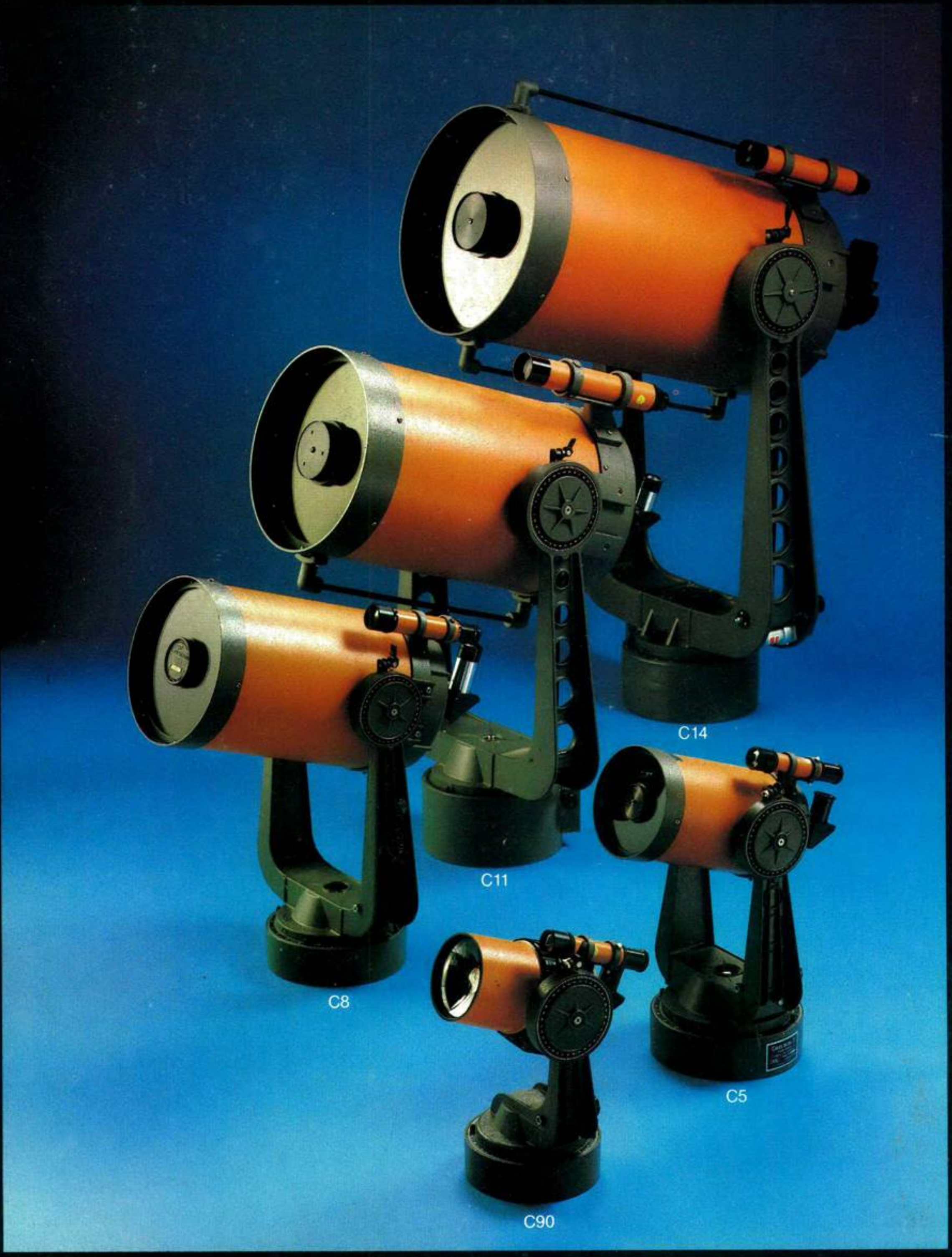

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